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SEDIMENT TRANSPORT, WATER QUALITY AND CHANGING BED CONDITIONS, TUCANNON RIVER, WASHINGTON

SEDIMENT TRANSPORT, WATER QUALITY, AND CHANGING BED CONDITIONS, TUCANNON RIVER, SOUTHEASTERN WASHINGTON

Prepared For

USDA Soil Conservation Service

Spokane, Washington

April, 1982

This report presents the results of studies conducted as part of the Tucannon River Water Quality and Aquatic Habitat Investigation by H. Esmaili & Associates, in association with D. W. Kelley & Associates, and in close cooperation with the staff of the USDA Soil Conservation Service, Washington State Office. It is part of a larger USDA Cooperative River Basin Study, coordinated by Gary L. Johnson, River Basin Planning Staff Leader with SCS.

Other studies undertaken as part of this contract are presented in a separate companion report entitled "Ecological Investigation of the Tucannon River, Washington".

The findings of both studies are summarized in Chapter 8 of this report.

Tucannon River Water Quality and Aquatic Habitat Study

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INTRODUCTION

Background of Study.

Since the early decades of the century, accelerated rates of erosion in the fertile loessial soils of eastern Washington have been a major source of environmental concern. High rates of erosion began with intensive cultivation of the upland areas throughout the dryland wheat belt of Washington, Idaho, and Oregon. The Soil Conservation Service has been active since the 1930's throughout southeastern Washington in limiting soil loss. Recently, there has been growing interest in the downstream effects of soil loss. Two important recent factors contributing to this interest are the passage of Public Law 92500, aimed at restoring fishable and swimmable waters, and widespread concern over rapid decline of the steelhead and salmon populations in the Columbia and Snake River systems during the past two decades.

The studies described in this report were intended to:

1. Identify the effects of water quality -- including sediment -- on aquatic habitat in the Tucannon River.
2. Define other factors and influences significantly affecting aquatic populations in the stream.
3. Provide a basis for discussing the effects of land use and other watershed influences on the stream and related habitat.

The results and findings will be used by the staff of SCS and other cooperating agencies in planning conservation practices in the four-county southeastern Washington region.

The study was conducted by H. Esmaili and Associates, Inc., in association with Don W. Kelley, Aquatic Biologist, under contract to the USDA Soil Conservation Service.

Staff professionals from SCS and other cooperating agencies worked closely with the contracting team, and participated in most facets of the study. The study began late in October 1979, with data collection ending in June 1981.

Study Area

The Tucannon River drains approximately 500 square miles in Columbia and Garfield Counties in southeastern Washington. The river heads in the rugged volcanic highlands of the northern Blue Mountains, with maximum elevations approaching 6,500 feet. The southern part of the basin is devoted to wilderness, forestry, and rangeland uses. Much of these headwater areas is within Umatilla National Forest or in various holdings of the Washington State Department of Game and Fish.

Emphasis in this study is on the northern two-thirds of the basin. This area is one of deep, productive soils developed on extensive windblown silts. Pataha Creek, a large right-bank tributary, drains a largely agricultural watershed, including most of the basin within Garfield County. North of the National Forest, the Tucannon River and its major tributaries flow through relatively narrow alluvial bottomlands incised 500 to 1,500 feet into the silt-mantled uplands. The Tucannon River flows into the Snake River near Starbuck, Washington at an elevation of about 500 feet.

The regional economy is based on agriculture. Wheat is the predominant crop, as it has been for the past century. Most of

TUCANNON RIVER AND PATAHA CREEK WATERSHEDS
COLUMBIA and GARFIELD COUNTIES

Tucannon River Water Quality
and
Stream Habitat Study

Prepared for: USDA Soil
Conservation Service

MONITORING STATIONS, WY1980

A Hatchery (DA=96 mi^2; S=0.018)
Q*, SS, BS, WQ, DO, HC

B Krouse Ranch (DA=218 mi^2; S=0.0076)
Q, SS, BS, WQ, DO, HC, SD, SL, BME

C Pataha Cr. at Pomeroy (DA=77 mi^2; S=0.0104)
Q, SS, BS, WQ

D Pataha Cr. at Chard (DA=146 mi^2; S=0.0051)
Q*, SS, BS, WQ

E Smith Hollow Rd. (DA=4.31 mi^2; S=0.0037)
Q*, SS, BS, WQ (USGS gage site)

F Powers Road (DA=500 mi^2; S=0.0075
Q, SS, BS, WQ, SD, SL, DO, HC, BME

G Marengo (DA=156 mi^2; S=0.011)
DO, HC, SD, SL

H Camp Wooten (DA=90 mi^2; S=0.012)
DO, HC, SD, SL, BME

J Helley Fletcher Ranch (DA=453 mi^2; S=0.0045)
DO, HC, SD, SL

ABBREVIATIONS

Q	Discharge
SS	Suspended sediment
BS	Bedload sediment
WQ	Water quality
SD	Scour devices
SL	Scour lines
DO	Dissolved oxygen
HC	Hydraulic conductivity
BME	Embeddedness and particle sizes of bed
DA	Drainage area
S	Local slope of channel
*	Automatic recorder

Figure 1.1.

Topographic Map of Tucannon Watershed and Vicinity. Monitoring program is explained in Appendix A and in text.

the wheat is dryfarmed in the rolling upland areas, intermixed with other small grains, notably barley. Alfalfa, asparagus, and various legumes are also grown in the area, largely on alluvial soils along the larger streams. Both the valley floors and slopes are used to support a limited number of livestock.

Climate. The basin has a continental climate, with some marine influences. In the northern part of the basin, the mean annual temperature is generally about 63°F. Maximum daily temperatures average about 85°to 90°F in mid-summer, and about 35 to 40°F in mid-winter. Sustained periods of sub-freezing weather are common; the soils often freeze to depths of 10 to 20 inches. Mean annual precipitation increases from about 10 inches near the Snake River to over 40 inches in the upper parts of the Blue Mountains. Rainfall occurs primarily during the winter months as frontal storms pass through the area. Both frontal and convective storms occur during late spring and early summer. Rainfall during the dry late-summer months is primarily from convective events (Table 1.1).

In the northern part of the basin, most of the runoff and peak flows occur during the winter and early spring. Runoff as a proportion of rainfall varies sharply with antecedent moisture and the extent of frozen ground. The Tucannon River and Pataha Creeks exhibit snowmelt rises during late-April, May, and June, then gradually subside toward base flow.

Stream Network. Three types of streams can be recognized in the area. Streams of the Blue Mountains have high rates

Table 1.1. Monthly Precipitation Variation

Month	Mean Monthly Precipitation[a]		Precipitation, Water Year 1980[b]		
	Dayton[c] (in.)	Pomeroy[d] (in.)	Pomeroy (in.)	Emerson[e] (in.)	Kimble[f] (in.)
October	1.89	1.50	1.82	1.66	1.84
November	2.38	1.91	1.61	1.52	1.73
December	2.70	2.26	1.64	2.11	3.05
January	2.43	2.02	3.89	2.58	3.78
February	1.90	1.63	1.20	1.19	1.34
March	2.12	1.66	2.18	1.15	2.77
April	1.56	1.27	0.69	0.66	1.04
May	1.46	1.29	2.59	2.31	4.49
June	1.51	1.49	0.87	1.54	4.42
July	0.40	0.32	0.54	0.23	1.33
August	0.36	0.38	0.59	0.57	0.80
September	0.82	0.85	1.23	1.33	1.72
Annual Total	19.53	16.58	18.85	16.85	28.31

a/ Source: Phillips, E.L., 1974.
b/ Data provided by Buzz Houtz; USDA Soil Conservation Service, Pomeroy.
c/ Period of Record: 1901-1960.
d/ Period of Record: Not specified.
e/ In upper Dry Hollow watershed near Marengo.
f/ Near National Forest boundary, 3 miles south of Columbia Center.

of mean runoff per unit area, generally with a peak flow occurring in the period of maximum snowmelt. They have low rates of sediment transport and, generally, outstanding water quality.

The lowland streams may be distinguished based on whether or not they serve as groundwater drains. Streams receiving groundwater usually support at least a minimal, nearly-continuous strip of riparian vegetation. Only isolated patches of woody riparian plants occur along streams or reaches which do not intercept the major water-bearing zones. Willow Creek and Dry Hollow are examples of the two types of stream corridors. Willow Creek supports a narrow, but continuous, riparian zone, and provides habitat for associated fauna. Dry Hollow, a nearby stream draining a watershed of nearly identical size, soils, and rock types,is nearly devoid of woody streamside vegetation. Both types of lowland streams convey runoff mainly during the winter months, often with high sediment transport rates and variable water quality.

Most of the larger streams are of mixed type in their lower reaches.

The lowland streams and the main rivers in their lower reaches have several unusual attributes:

1. During major storm events, suspended sediment concen- can be very high. Concentrations exceeding 200,000 milligrams per liter were reported in the Tucannon River during the 1964 and 1965 floods. Concentrations were about twice as high in Deadman and Meadow Creeks, immediately to the north.

2. The beds, banks, and transported sediment are all remarkably deficient in sand and fine gravel. Bed and bank sediments are composed mainly of coarse gravel. Bed and bank sediments are composed mainly of coarse gravel and cobbles, with an important but subordinate amount of silt and clay as a matrix. Generally, less than 3 to 5 percent of the sediment load is sand-sized material.
3. The lowland streams convey large loads of finely-divided organic matter, principally small fragments of grain stalks, grasses, and leafy riparian debris. This material affects the intra-gravel environment in several ways, primarily by depleting dissolved oxygen and perhaps diminishing the rate of water movement through the bed.
4. Most of the larger stream channels have unstable beds and banks. This is especially true of the lower Tucannon River, discussed in Chapter 6. Virtually all other drainages have well-developed channels, often cut to bedrock control. The wide alluviated swales and flats found elsewhere in eastern Washington and Oregon, in which small roadside ditches serve as the main runoff channel, are almost entirely lacking in the Tucannon watershed and in other lowland areas of Garfield and Asotin Counties.

<u>Antecedent Conditions.</u> Conditions during the previous several years often affect streamflow, sediment transport, and

water quality. Runoff in the Tucannon basin had been below normal since late 1976. This followed a period, 1969 through 1976, during which runoff had been 25 percent above the long-term mean. Water year 1977 was by far the driest year recorded in the area. The principal floods affecting the channel occurred in the winter of 1964-1965; these are discussed in the next chapter. Recent major runoff peaks occurred in 1969, 1971, 1972, and 1974. No moderate- or high-recurrence events had occurred during the preceding 6 years.

Watershed Conditions, Water Year 1980. Runoff during water year 1980 was slightly below average for the period of record in the Tucannon basin. Winter precipitation was above average in the northern part of the watershed, and about 75 percent of normal in the Blue Mountains. Rainfall during May approached the recorded maxima for the month at several stations; we suspect that suspended sediment concentrations during the snowmelt season were greater than normal due to runoff from the lower basin.

Unusually warm rains and high runoff during a four-day period in mid-January produced much of the storm runoff and sediment yields throughout the basin. A major mud avalanche affecting most of the Bear Creek sub-basin, one of the larger headwater catchments, likely occurred during this period of warm, intense rainfall. The effects of this storm are further discussed in Chapter 3 and 4.

A cloudburst on June 16 generated the greatest flows of the year in the lower portions of the basin. Rainfall data for this event collected by Duane Scott and his interpretation of the storm path are shown in Figure 1.2. The storm altered bed conditions at three of the monitoring sites below Willow and Pataha Creeks, but had little effect elsewhere in the basin.

Ash from the eruptions of Mount St. Helens fell on the watershed beginning on May 18, 1980. It accumulated in measurable quantities only along the northern edge of the basin. We observed 0.01 inch and 0.07 inch in rain gages at the Krouse Ranch and at Powers Road, respectively; Pomeroy reported less than one-sixteenth of an inch. The total estimated ashfall in the watershed was roughly equivalent to the sediment yield during the 1980 water year. We do not believe that the ashfall resulted in measurable increases in sediment loads.

<u>Previous Investigations Streamflow.</u> Streamflow has been gaged at one time or another on most major streams in southeastern Washington. Important long-term records have been collected in the Walla Walla and Milton-Freewater areas, where some streams have been monitored nearly continuously for the past 50 to 60 years. Otherwise, prior to about 1960, the gaging record for the major streams of the region generally was discontinuous, with little overlap on the periods of record. Streamflow has been measured on most of these larger streams near their mouth since the late-1950's or early 1960's, including the Walla Walla, Touchet, and Tucannon Rivers, plus Asotin Creek. Streams of intermediate size, such as Pataha or Alpowa Creeks, and some

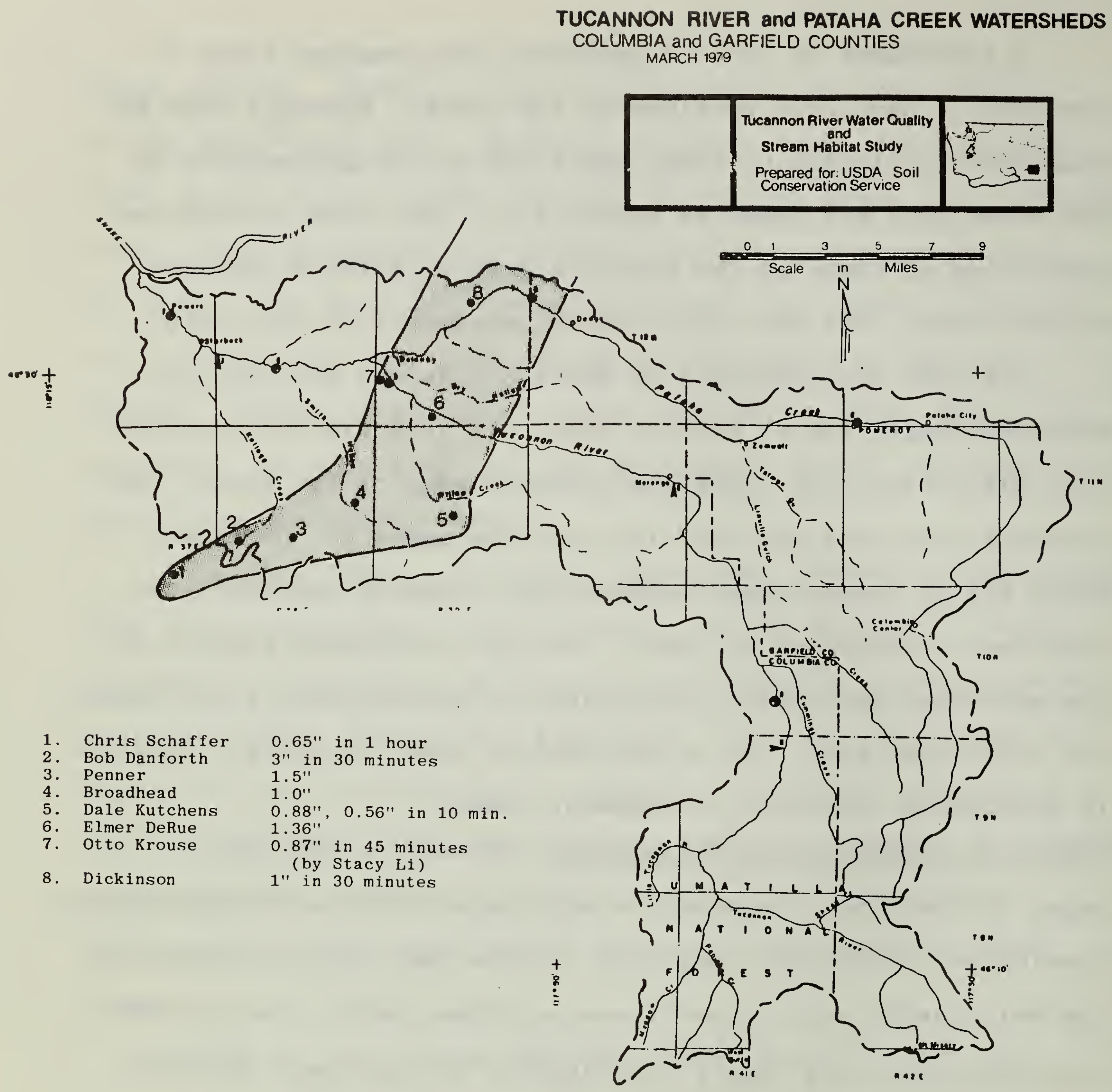

Figure 1.2. Reported Amounts and Intensities of Rainfall During the Storm of June 16, 1980. Inferred path of the main storm cell is shown. Data collection and interpretation by Duane Scott (SCS, Dayton).

of the larger headwater streams, have intermittent monitoring histories. Smaller ephemeral streams, generally those with watersheds of less than 40 to 50 square miles, have been monitored widely, but in a limited manner. The U.S. Geological Survey staff (e.g., Haushild, 1979) indicate that better definition of the runoff regime from these streams is one of the most pressing data needs in the region*. The significant gaging histories for streams in and near the Tucannon watershed are summarized in Table 1.2.

In addition to data collection, there have been a number of efforts to develop records for basins lacking significant histories of monitoring. The most important of these for the 1980 Tucannon watershed analysis are the synthetic streamflows developed by the Bureau of Reclamation for the proposed dam on the Tucannon River near Camp Wooten, and various studies attempting to develop flood frequency relations on a regional basis (e.g. Bodhaine and Thomas, 1964; Haushild, 1979).

<u>Suspended Sediment.</u> Suspended sediment transport was monitored in a number of streams in eastern and southeastern Washington during the 1960's. Basin-wide studies of suspended sediment discharge were conducted in the Walla Walla and Touchet watersheds (Mapes, 1969) and the Palouse watershed (Boucher, 1970) by USGS staff scientists during the 1963 through 1965 water years. These

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* Haushild (1979, p.3) states that existing studies ". . . indicate either a non-applicability of, or some lack of confidence in, the equations and methods developed to estimate floods in the small ephemeral streams of eastern Washington." He defines these streams as those with drainage areas smaller than 40 square miles, with less than 30 percent forest cover.

Table 1.2. Gaging Histories: Tucannon River Basin and Vicinity[a]

Location	Discharge: Continuous	Discharge: Partial Record Crest Stage	Water Quality: Suspended Sediment	Water Quality: Temperature	Water Quality: Mineral Analysis
Tucannon River Basin					
Tucannon River					
near Starbuck	Oct. 1914 to Sept. 1917 Aug. 1928 to Sept. 1931 Oct. 1958 to present		Oct. 1962 to June 1970	Oct. 1962 to June 1970	1973-1974
near Power				1974, 1977 to present[b]	1974, 1977 to present[b]
near Delaney					1959-1960
Kellogg Creek					
tributary no. 1		1963 to 1965			
tributary no. 2 near Starbuck		1965 to 1970 1970 to 1978			
Walla Walla River Basin[c]					
Touchet River					
at Bolles	Feb. 1924 to Oct. 1929 April 1951 to present		July 1962 to Sept. 1965[b]	Nov. 1969 to May 1971	Oct. 1973 to Sept. 1975
near Dayton				Oct. 1973 to Sept. 1975[b]	Oct. 1973 to Sept. 1975[b]
East Fork near Dayton	April 1941 to Sept. 1951 Sept. 1956 to Sept. 1968				
Dry Creek	Jan. 1949 to Sept. 1967				
Mill Creek above Blue Creek	Aug. 1913 to Sept. 1917 Oct. 1939 to Sept. 1976		March 1962 to July 1965	March 1962 to July 1965	
Blue Creek	Oct. 1939 to Sept. 1971				
Mill Creek below Blue Cr., near Walla Walla			Oct. 1962 to June 1970	Oct. 1962 to June 1970	
Other Snake River Tributaries[c]					
Deadman Creek near Central Ferry	April 1963 to Sept. 1974		Oct. 1963 to June 1970[b]	Oct. 1963 to June 1970[b]	
Meadow Creek near Central Ferry	1963 to 1974	1975 to present			
Asotin Creek near Asotin	1904 1928-1942 Sept. 1958 to present				

[a] Partial-record station, miscellaneous discharge measurements are available for various other drainages in the area

[b] Partial records only

[c] Gages operate solely as partial-record crest-gages are included in Table 2.3.

were based on procedures and equipment similar to those used during WY1980 in the Tucannon basin. Observations made during these studies (and on other local streams, such as the Tucannon) are especially informative in that they include the storms of February, 1963, December, 1964, and January, 1965 -- three of the more significant events of the past half-century. Additionally, a few analyses of the size distributions of suspended sediment and bed-material samples drawn from many streams in southeastern Washington and adjacent Whitman County were developed.

Long-term studies of annual erosion rates have been made by Verle C. Kaiser since the mid-1930's on standards plots throughout Whitman County, across the Snake River from the Tucannon basin. His observations are among the very few sustained and systematic records of erosional processes in the general region. Among his conclusions of particular importance for the present analysis of the Tucannon watershed is that sediment delivery to the active channels is small relative to the amount of detached soil; the difference is deposited at the base of slopes and in swales. He also noted that soil loss (and, presumably, sediment delivery) is not in simple relation to rainfall or runoff, but depends to a great degree on antecedent ground temperature and moisture conditions, and on effective rainfall intensity. Equally significant, Kaiser's data suggest that erosion rates may range through cycles of perhaps 10 to 15 years (Boucher, 1970; McCool and Papendick, 1975), complicating definition of "average" or "normal" soil loss and sediment yields.

Other applicable observations of suspended sediment transport include monitoring results from two streams near Pullman (South Fork Palouse River and Missouri Flat Creek), and seasonal observation of transport rates developed by Forest Service staff.

Bedload Sediment Yields. Other than the important studies on the Snake and Clearwater Rivers near Lewiston (e.g. Emmett and Seitz, 1974), no bedload transport monitoring had been attempted in southeastern Washington prior to this analysis. As part of their basin-wide studies, the U.S. Geological Survey staff estimated the bedload component of total sediment yield to be 3 to 10 percent in the Walla Walla and Touchet watersheds (Mapes, 1969), and 2 to 8 percent in the Palouse basin. These were fundamentally best-guess estimates by experienced observers familiar with the area, based in part on Colby's method for estimating bedload movement in sand-bed streams. Procedures and equipment to monitor transport rates along the bed had not been developed at the time these studies were made.

Sediment Yield Influences. Mc Cool and Papendick (1975) further discussed the variability of sediment yields in Palouse-type watersheds. They noted that daily, seasonal, or annual variability in yields is very large in the small-grain dryland region of the Pacific Northwest. Individual runoff events can account for half or more of the annual sediment yield. Sediment transport during a given year or a large single storm can be as large as the total of 4 or 5 other years. Intensive sampling during storms should be the basis of any field program. Mc Cool

and Papendick concluded that "(s)ampling programs based on weekly samples, even at stations with excellent streamflow records, can give extremely misleading results. Sampling programs of 1 to 2 years duration can also give extremely misleading results." This work indicated that factors other than rainfall and runoff were responsible for much of the annual variability in yields. In subsequent work, McCool has emphasized the distribution of frozen ground as a dominant factor in soil loss during individual storms.

Another indication of the importance of ground conditions derives from studies of flood frequency in the ephemeral streams of eastern Washington (Haushild, 1979). One major finding of Haushild's investigation is that longitude is a more effective predictor of flood magnitude than either mean annual precipitation or 24-hour rainfall amounts. Areas in the western part of the Columbia basin tend to be appreciably warmer than the higher areas to the east with more intensely continental climates. This finding may be interpreted as a suggestion that antecedent moisture buildup and extent of ground freezing may be dominant influences upon runoff, erosion, and sediment transport rates.

Previous assessments of aquatic habitat and populations in the Tucannon are discussed in a companion volume.

Scope of Studies.

A year-long study of streamflow, sediment transport, and water quality began in October, 1979 and continued through the following September. Gages were established at six locations,

and monitored through the year, most intensively during runoff events. Five bed-monitoring sites on the main stem of the Tucannon River were also established at the onset of the study. The intra-gravel environments at these sites were described with arrays of mini-piezometers, standpipes, and scour devices, with emphasis on dissolved oxygen levels, field permeability, and stability of the bed. During the following spring, arrays of cross-sections were installed at these sites to establish changes in bed configuration and the character of the bed surface during snowmelt and the summer months, the period of maximum biotic activity in the stream. Primary and secondary productivity were measured at these sites. Rearing habitat was systematically inventoried along the full length of the river downstream of Panjab Creek. Most sites were affected by runoff from a major cloudburst which occurred over the central portion of the basin in mid-June. A summary of instrumentation installed at each sites is presented in Appendix A.

At the conclusion of the year's study, it became evident that factors other than sediment and water-quality were strongly affecting habitat values. There was also much of importance regarding the stream and its resources that had not been addressed due to the specific objectives of the first year's program. A number of specific questions were approached during continuation studies. Primary among these were the changes in the channel and its related affect on summer water temperatures. The form and pattern of the channel were analyzed and compared with other

streams in southern and eastern Washington, and elsewhere in the region. The composition of the bed, the rate of fine-sediment accumulation in interstices within the bed, and interstitial water quality were intensively studied in the lower half of the stream system. An investigation was also made of the fall chinook run reported to spawn in the lower two or three miles of the river.

Results of these studies have been analyzed and interpreted during the subsequent months.

Organization of the Report.

This report describing the 1980 Tucannon basin study is presented in two volumes. The first, prepared by Don W. Kelley and his associates, discusses the habitat conditions and the significant local environmental influences on fish and other aquatic organisms. This volume describes the channel of the Tucannon River and the hydrologic, geomorphic, and water quality factors affecting it. A summary of principal findings in both volumes is presented in the final chapter.

Notation and Conventions.

Studies of habitat conditions are not only inherently complex, but of necessity attract readers with varied backgrounds. Several clarifying remarks may prove helpful.

First, measurements of hydraulic and sediment parameters are inherently inexact. Unfortunately, it has become customary to express many observations or analyses as values that apparently are accurate to 5 or 6 significant figures. Most sediment transport data, in particular, merit only two significant figures; rarely are more than three figures warranted. Readers are cautioned

that implied precision exceeding two digits is probably misleading. Data developed for this study are presented in as detailed a manner as reasonable. Rounding is employed throughout this study. Discrepancies of up to 5 percent may result from this practice and should not be a source of concern.

Second, streamflow and sediment budgets are conventionally conducted on three-year basis. This allows monitoring of a larger range of environmental conditions, and a broader sample of storms. In southeastern Washington, where much of the mean sediment yield occurs during the largest several storms per decade, a base period longer than one year is generally indicated. Formal sediment, water quality, and streamflow budgets which have been conducted in region have all incorporated three years of study (Mapes, 1969; Boucher, 1970; Emmett and Seitz, 1974; Emmett, 1975). A one-year period of record is however, fully appropriate for the broader purposes of a study of water quality and habitat conditions. Comparisons between studies with the different periods of record can be problematic.

Third, an important convention in geomorphology and field hydrology is the use of eye-fitted curves, particularly during the first few years of data collection. Under storm conditions, each measurement may have a different validity due to any number of factors known only to the field observers. The observers are considered best qualified to weight the measurements and develop the most probable relations. In the past, the convention also has had the advantages of convenience and a savings of time. These

TABLE 1-3 VARIOUS SIZE GRADE SCALES IN COMMON USE

Udden-Wentworth	ϕ values	German Scale† (after Atterberg)	USDA and Soil Sci. Soc. Amer.	U.S. Corps Eng., Dept. Army and Bur. Reclamation‡
		(Blockwerk)		
Cobbles		—200 mm—	Cobbles	Boulders
			—80 mm—	—10 in.—
—64 mm—	−6			Cobbles
Pebbles		Gravel (Kies)		—3 in.—
				Gravel
—4 mm—	−2		Gravel	
				—4 mesh—
Granules				Coarse sand
—2 mm—	−1	—2 mm—	—2 mm—	—10 mesh—
Very coarse sand			Very coarse sand	
—1 mm—	0		—1 mm—	
Coarse sand			Coarse sand	Medium sand
		Sand		
—0.5 mm—	1		—0.5 mm—	
				—40 mesh—
Medium sand			Medium sand	
—0.25 mm—	2		—0.25 mm—	
Fine sand			Fine sand	Fine sand
—0.125 mm—	3		—0.10 mm—	
Very fine sand			Very fine sand	—200 mesh—
—0.0625 mm—	4	—0.0625 mm—		
			—0.05 mm—	
Silt		Silt		
			Silt	Fines
—0.0039 mm—	8			
		—0.002 mm—	—0.002 mm—	
Clay		Clay (Ton)	Clay	

† Subdivisions of sand sizes omitted.

‡ Mesh numbers are for U.S. Standard Sieves: 4 mesh = 4.76 mm, 10 mesh = 2.00 mm, 40 mesh = 0.42 mm, 200 mesh = 0.074 mm.

no longer are true due to the ready availability of pre-programmed hand calculators or desktop computers. The practice is retained because eye-fitted curves have proven to be the more accurate predictors of actual measurements at a later date. Other means of curve-fitting may be used once the field studies have been completed and the sampled population(s) can be more rigorously defined. This convention is discussed in a number of recent or local publications (e.g. Emmett and Seitz, 1974; Dunne and Leopold, 1980).*

Fourth, the geologic classification ("Wentworth scale") of particle sizes is used throughout this study, due to its prevalent use in the region. Table 1.3 establishes the relationship between this and classifications used by the Forest Service and the Corps of Engineers.

Fifth, with the exception of particle sizes, foot-pound-second units are used throughout the report.

Finally, hydrologic data are usually expressed on the basis of a water year, which is defined as the period beginning October 1 and ending the following September 30. The notation WY1980, for example, refers to the water year beginning October 1, 1979. The period of October 1, 1980 through September 30, 1981, is designated as WY1981.

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* Eye-fitted curves: the generalized line passing through point data on graphs for meaningful trends, commensurate with accuracy and validity of the field measurements.

Acknowledgments.

This study was conducted under the sponsorship of the USDA Soil Conservation Services, under the direction of Gary L. Johnson, River Basin Planning Leader. Chester A. Jahns, Ivan Lines, Paul Rogers and John A. Wilson of the SCS staff participated regularly in the design and conduct of the study. Throughout the project, we have had the benefit of advice and assistance from Dr. T.C. Bjornn and Dr. Michael Falter, of the University of Idaho. Phillip R. Boucher provided much helpful data from the U.S. Geological Survey office in Pasco, including important archival materials. Staff members from nearly a dozen cooperating agencies participated in the study in an advisory role.

The suggestions, advice, and hospitality extended by Boyden ("Buzz") Houtz, District Conservationist, and Don White of the SCS staff in Pomeroy and Duane Scott, District Conservationist in Dayton - are gratefully acknowledged. Bill Hubbard, biologist at the Tucannon Hatchery, assisted the project in many ways. Dave Johnson, of Pomeroy, worked with us in establishing and surveying the bed-monitoring sites. Similarly, we appreciate the access, perspective and assistance provided by many residents along the river, most notably the Otto Krouse and Helley Fletcher families.

CHAPTER 2

HISTORY OF THE TUCANNON RIVER CHANNEL AND RIPARIAN ZONE

> The Tokanon at its mouth is but a brook in summer, across which one may step on the larger stones strewn along its channel without wetting one's feet. The Pataha was dry in its lower course when I visited its valley in August, and had shrunk back as far as Pomeroy.
>
> (I.C. Russell, 1897)

> The picturesque and piscatorial Tucanon, of historic fame, and the drainage stream of one of the richest and most beautiful valleys in the state, passes right through town (Starbuck) and its bright waters impart a needed verdure to the rather arid land as well as diffuse a grateful coolness to the sometimes intense heat . . .
>
> (Lyman, 1918, p 351)

The channel of the Tucannon River and the belt of trees and shrubs along the stream have historically been important in supporting human, wildlife, and fish populations in the region. The river's name may be traced to the word for the couse root, from an edible riparian plant widely used by the Nez Perce (Lyman, 1918). Thickets along the banks of Pataha ("Brushy") Creek provided game, fuel, and shelter (Sherfey, 1975).

In recent years, the channel of the Tucannon River has widened and steepened. The proportion of streambanks stabilized and shaded by streamside woodlands has decreased. Migration of the channel and instability of its bed has increased.

Dikes and revetments discontinuously line many miles of the stream from Camp Wooten to its mouth. Many or most of these changes occurred primarily during the 1960's and may be associated with extreme floods. These floods, to a certain extent, aggravated and accelerated changes which had been occurring for many decades.

Evolving channel conditions and the history of runoff and storms in the Tucannon River are described in this chapter. Perhaps more so than in most basins, management of water quality and habitat values in the Tucannon watershed may be strongly influenced by the nature and probable causes of these changes.

Runoff and Storm History.

Three principle sources of recorded information on the conditions in the channel are available in the Tucannon Basin:

1. Historical records, including the primary accounts of local residents and itinerant scientists and observers, plus the important local historical syntheses.
2. Data collected by state and federal agencies in the course of their regular or routine activities; gaging records of the U.S. Geological Survey and the records and aerial photography of the ASCS are the most important of this class.
3. Special studies conducted by Federal, State, or local agencies, such as those resulting from development of the Snake River Dams or from the floods of 1964 and 1965.

Numerous documents in each category were reviewed for this analysis; additional significant materials undoubtedly exist in the archives of the individual agencies. It was not possible

within the scope of this study to effectively develop an important additional source of information--the observations of local residents familiar with specific portions of the Tucannon River channel. Both Garfield and Columbia Counties have active historical societies capable of evaluating and expanding upon the material discussed in this chapter.

Annual Runoff History. Mean annual runoff from the Tucannon watershed may be roughly reconstructed using records of other streams in the region. Streamflow histories used in this analysis are described in Table 2.1. The statistical relations between these records and those developed for the lower Tucannon River are also shown in this table.

The annual runoff record, both actual and synthesized, serves as the basis for the channel history presented in Table 2.2. It should be noted that runoff from many southeastern Washington basins is cyclic. Although data are limited, runoff in the region appears to have been less than normal during much of the 1930's and 1960's. For example, runoff from the South Fork of the Walla Walla River and the Asotin Creek were below long-term averages for 9 consecutive years beginning in 1934. Only WY1965 produced greater than normal runoff at most stations during the period 1960 through 1968. Conversely, runoff was above normal for 8 to 10 consecutive years beginning in the mid-1940's.

Storm History. Variability of storm runoff within the general southeastern Washington region is very large. Commonly, major events in one basin are reflected as a relatively minor

Table 2.1. Relation of Mean Annual Runoff, Tucannon River and Adjoining Streams

Station Description						Mean Annual Runoff			Relation to Tucannon River near Starbuck			
Station No. (USGS)	Stream, Station	Station Elevation (ft.)	Drainage Area (sq.mi.)	Basin Type	Period of[a] Record	Observed[b] (cfs)	Unit (cfs/sq. mi.)	Common Record	Linear Regression[c]	Standard Error (afa)	R^2 [c]	Basis For Synthetic Record (years)
13344500	Tucannon R. near Starbuck, Wash.	600	431	mixed	1915-17 1929-31 1959-pres.	177	0.41	1915-17 1929-31 1959-pres.	Y=X	0.0	1.00	1915-17 1929-31 1959-pres.
608	Tucannon R.[f] at Marengo, Wash.	1470	160	Blue Mtn.	1914-15[g] 1925-30	126	0.79	1915[g] 1929-30 1980[h]	Y=56200 + 1.90X	5800	0.933	1914
14017000	Touchet R. at Bolles, Wash.	1150	361	mixed	1924-29 1951-pres.	220	0.61	1929 1959-pres.	Y=28400 + 0.579X	12800	0.961	1925-28 1952-58
14016500	East Fork Touchet R. near Dayton, Wash.	1860	108 102	Blue Mtn.	1942-51	120	1.11	1959-68	Y=-9300 + 1.50X	4300	0.986	1942-51
13334700	Asotin Cr. near Asotin, Wash.	1090	170	mixed	1929-42[i] 1960-pres.	76.9	0.45	1929-31 1960-pres.	Y=-9900 + 2.49X	13100	0.923	1932-41
14010000	South Fork Walla Walla R. near Milton, Ore.	2050	63	mixed	1909-15	174	2.76	1915	Y=-90900+1.66X	18.800	0.842	1909-13
14026000	Umatilla R. at Yoakum, Ore.	768	1270	Blue Mtn.	1903-pres.	670	0.53	1915-16 1929-31 1959-pres.	Y=29800 + 0.215X	29500	0.633	1905-08 1918-24
13351000	Palouse R. at Hooper, Wash.	1040	2500	mixed	1898-99 1901-04 1914-15 1952-pres.	596	0.24	1915 1959-pres.	Y=55600 + 0.175X	22,300	0.767	1898-99 1901-04

a/ Water years for which complete annual data is available.
b/ Mean annual runoff for the period of record.
c/ Equation of the form Y= a+bX; Y= Estimated annual runoff in Tucannon R. at Starbuck, from X, measured runoff at other station. All units in acre-feet per year (afa).
d/ Standard error of the equation. About 64 percent of the estimated runoff values will be within one standard error of the true value; about 95 percent will be within two standard error. Units = afa.
e/ Coefficient of determination, a measure of goodness of fit.
f/ USGS station. "Tucannon River near Pomeroy," located at Marengo bridge, and approximately one-half mile downstream from the Marengo bed-monitoring site (G).
g/ Data for WY1915 available through June 30, and extended through September 30 by correlation to gaged flow in the Tucannon River at Starbuck.
h/ Estimated runoff in WY1980 is about 88200 acre feet, based on interpolation by proportional drainage areas between runoff observed at the Hatchery (adjusted) and Krouse Ranch gages; this study .
i/ During 1929-1942, gaging station situated 1 mile upstream, above Kearny Gulch, where drainage area is 156 square miles (USGS Water-Supply Paper 1317). Mean annual runoff for this period was adjusted upward by the ratio of drainage areas prior to regression.

Table 2.2. History of Channel Influences, Tucannon River Basin

Year	Estimated Runoff	Correlate Station	Remarks
1898	183,900	Palouse R. at Hooper	Previous floods in 1862,
1899	124,700	"	1878, 1890, and 1894.
1900	-	-	Flooding in Pomeroy, Feb.
1901	182,000	Palouse R. at Hooper	& Apr.
1902	114,800	"	
1903	169,800	"	
1904	165,100	"	Major flood, Asotin Cr.
1905	156,000	Umatilla R. at Yoakum	
1906	-	-	
1907	112,000	Umatilla R. at Yoakum	
1908	102,400	"	
1909	124,900	South Fork Walla	
1910	121,900	Walla R.	Major storms through region
1911	88,600	"	First sewage treatment plant
1912	130,200	"	at Pomeroy.
1913	138,500	"	Intensification of upland
1914	105,300	Tucannon R. at Marengo	small-grain cultivation
1915	76,000	Tucannon R. nr. Starbuck	(Boucher, 1970).
1916	197,000	"	Major flood (5700 cfs near
1917	210,000	"	Starbuck; greatest flood of
1918	189,800	Umatilla R. at Yoakum	record at Pomeroy).
1919	-	-	Beginning of widespread
1920	-	-	mechanized agriculture
			(Sherfey, 1976).
1921	-	-	
1922	162,700	Umatilla R. at Yoakum	
1923	118,700	"	
1924	112,200	"	
1925	116,400	Touchet R. at Bolles	
1926	71,700	"	
1927	150,600	"	
1928	176,100	"	
1929	79,300	Tucannon R. nr. Starbuck	
1930	78,900	"	Flood (6000cfs) reported
			at Starbuck. Minimum flow
1931	76,200	"	of record (15cfs). Hillside combines introduced
1932	133,500	Asotin Cr. near Asotin	during 1930's.
1933	137,200	"	Driest decade of record.
1934	120,500	"	Initial organized conser-
1935	94,700	"	vation measures.
1936	116,300	"	
1937	81,100	"	
1938	120,300	"	
1939	94,000	"	
1940	83,000	"	

Year	Estimated Runoff	Correlate Station	Remarks
1941	93,600	Asotin Cr. nr. Asotin	
1942	88,700	East Fork Touchet R.	
1943	136,100	near Dayton	
1944	63,900	"	Runoff estimate likely
1945	80,300	"	Beginning of wet decade.
1946	125,800	"	First widespread use of
1947	112,500	"	commercial fertilizers
1948	178,500	"	February, 1948 flood. 1949
1949	142,900	"	floods, Pataha Cr., Touchet
1950	163,400	"	R. Extreme peaks from cloud-
			bursts, Tatman sub-basin,
1951	163,500	"	1950.
1952	141,400	Touchet R. at Bolles	
1953	118,600	"	
1954	116,300	"	
1955	89,300	"	
1956	156,800	"	December 1955 floods
1957	113,500	"	Beginning of dry decade.
1958	118,800	"	
1959	144,900	Tucannon R. nr. Starbuck	
1960	110,400	"	
1961	117,100	"	
1962	110,400	"	
1963	96,700	"	February 1963 floods
1964	103,700	"	Major floods, December 1964
1965	200,300	"	and January 1965
1966	89,530	"	Cloudbursts, basinwide impact
1967	98,020	"	Lower Monumental Dam.
1968	82,110	"	
1969	167,000	"	Beginning of a wet decade.
1970	118,000	"	(runoff 25% above mean)
1971	145,700	"	
1972	198,200	"	
1973	88,410	"	
1974	236,500	"	Year of greatest recorded
1975	156,100	"	runoff.
1976	177,100	"	
1977	64,880	"	Drought
1978	111,700	"	
1979	116,300	"	
1980	114,600	"	Cloudburst in lower basin.

crest in adjoining drainages. Even within the same basin, floods of note in the lower reaches apparently did not affect upper portions of the channel dominated by Blue Mountain runoff. A notable example is the storm of February 1963. This event produced the greatest crest discharge in 40 years of record on the Palouse River at Hooper, and the third greatest in the 28 years of peak flow record on the Tucannon River; the same storm produced minor crests with recurrences of 1 to 2 years on the Touchet River (at Dayton, and at Bolles) and Asotin Creek. Similarly, the January 1974 storm produced record flows on Asotin Creek and the second greatest peak flow during the modern gaging period on the Palouse River at Hooper; crests on the Tucannon and Touchet Rivers were only slightly above average. This degree of variability within a relatively small region is probably primarily attributable to differences in ground conditions, notably the extent of frozen ground, snow accumulation, and antecedent soil moisture.

Universal in the channel histories of the southeastern Washington streams are the magnitude and impact of the December 1964 and January 1965 storms. One or the other of these events was the greatest flood of record at most southeastern Washington stations. This remains the case to date, with very few exceptions. Reports of damage to the channel and nearby structures and improvements occurred along all major streams. Commonly the relative magnitude of this event was greatest within the Blue Mountains and near the mountain front. The middle and headwater portions of

the channels--generally those of greatest value for spawning and rearing--were disproportionately damaged. Peak flows during these floods for most gaged streams in the region are presented in Table 2.3, which also includes known crests from other high-recurrence events.

Channel and Riparian Zone Changes, 1937-1978.

Many life-long residents of the area and the Soil Conservation Service staff discussed with us their impressions that the character of the river had fundamentally changed over a period of several decades. The principal perceived changes affecting long reaches of the stream included:

1. Long pools which previously had typified the stream had disappeared or been reduced to small fractions of their former volume.
2. Snags and fallen trees are much less abundant.
3. The channel appears to be wider and shallower.
4. The bed and individual bars appear more changeable or mobile.

Changes of this magnitude greatly affect the habitat values of the channel. A major focus of this investigation became documenting the extent of changes in the channel, evaluating potential causes of these changes, and discussing their implications for management of the river.

The primary basis for these studies are four sets of aerial photographs available for most of the central and lower portions of the river. These sets were taken in 1937, 1954, 1964 and 1978. All photographs were printed at a nominal scale of eight inches to the mile. We chose to work with the first and the most recent sets,

Table 2.3. Observed Peak Discharges During Storms of December, 1964 and January, 1965, and Other Extreme Events

Streams of Southeastern Washington and Nearby Areas[a]

			Maximum, Dec. 1964 and Jan. 1965				High-Flow Gaging History			
USGS Station Number	Stream and Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)	Peak Unit Runoff (cfs/ mi^2)	Estimated Recurrence[b] (yr)	Period of Record[c]	Peak Discharge (cfs)	Peak Unit Runoff (cfs/ mi^2)	Remarks
I. Southeastern Washington Streams										
A. North and East of Tucannon River Basin										
13347000	Asotin Cr. Below Kearney Gulch near Asotin, WA	170	12/23	2720	16.0	-	1904 1959-pres	-	-	1180 cfs in 1904 3700 cfs in 1974
13352000	Critchfield Draw near Clarkston, WA	1.80	12/22	196	108.9	8[d]	1959-1976	705	392	1964
13343450	Dry Creek at mouth near Clarkston, WA	6.83	12/22	463	67.8	10[d]	1963-1976	-	1200	-
1334520	Clayton Gulch near Alpowa, WA	5.6	12/22	142	25.4	3[d]	1961-1976[c]	298	53	1963
13343620	Tributary to South Fork Deadman Cr. near Pataha City, WA	0.54	12/22	43	79.6	3[d]	1961-1975	-	360	-
13343660	Tributary to Smith Gulch near Pataha City, WA	1.85	01/30	145	78.4	3[d]	1955-1974	-	360	- 254 cfs in 1961
13343680	Deadman Creek above Meadow Creek near Central Ferry, WA	135	12/22	1740	12.9	2.10[e]	1963-1974	5200	38.5	1963
13343700	Tributary to Ben Day Gulch near Pomeroy, WA	0.78	12/22	7	9.0	<2[f]	1961-1969	-	90	- 43 cfs in 1961
13343800	Meadow Creek near Central Ferry, WA	66.2	12/22	1910	28.9	-	1963-1974	2380	36.0	Sept. 14, 1966 2230 cfs in 1963
13352550	Tributary to Stewart Canyon near Riparia, WA	1.27	12/22	172	135.4	30[d]	1958-1975	277	220	1963
B. Tucannon River Basin										
13344300	Pataha Creek above Tatman Gulch at Zumwalt, WA	93.7	12/22	1360	14.5	-	1949	1620	17.3	1949
13344350	Linville Gulch near Pomeroy, WA	5.6	12/22	166	29.6	-	1950	9750	1741.1	1950
13344360	Skyhawk Canyon Creek (Nieble Grade) near Pomeroy, WA	7.48	12/22	261	34.9	-	1950	5200	695.2	1950
13344500	Tucannon River near Starbuck, WA	431.	12/22	7980	18.5	20[f]	1914-1917 1928-1931 1958-pres	*	*	6000 cfs in 1930

Table 2.3. (continued) Observed Peak Discharges During Storms of December, 1964 and January, 1965, and Other Extreme Events

Streams of Southeastern Washington and Nearby Areas[a]

USGS Station Number	Stream and Location	Drainage Area (mi^2)	Maximum, Dec. 1964 and Jan. 1965: Date	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Estimated Recurrence[b] (yr)	High-Flow Gaging History: Period of Record[c]	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Remarks
13344508	Tributary to Kellogg Creek near Starbuck, WA	6.0	12/22	1016	168.3	-	1965-1969	*	*	35 cfs in 1969
13344510	Kellogg Creek at Starbuck, WA	35.3	12/22	4000	113.3	-	1963-1965	*	*	2140 cfs in 1963
C. Touchet River Basin										
14016500	East Fork Touchet River near Dayton, WA	102	12/23	5450	53.4	1.48[e]	1941-1951 1956-1968	*	*	1530 cfs in 1948
14016600	Hatley Creek near Dayton, WA	4.12	12/22	205	49.8	6[d]	1955-1974	244	60	1963
14016650	Davis Hollow near Dayton, WA	3.01	12/22	62	20.6	7[d]	1956-1975	305	100	1956
14016740	Mustard Hollow at Dayton, WA	3.06	12/22	165	53.9	-	-	875	285.9	1956
14017000	Touchet River at Bolles, WA	361	12/23	9350	25.9	1.27[e]	1924-1929 1951-pres	*	*	7160 cfs in 1969 7140 cfs in 1972
14017030	Whetstone Hollow near Dayton, WA	14.9	12/22	271	18.2	1.61[e]	1949	790	53.0	1949
14017040	Thorn Hollow near Dayton, WA	2.68	12/22	218	81.3	12[d]	1962-1976	*	*	202 cfs in 1963
14017070	East Fork McKay Creek near Huntsville, WA	4.92	12/22	622	126.4	16[d]	1963-1976	733	149.0	1963
14017120	Touchet River at Lamar, WA	520	01/29	7800	15.00	-				
14017200	Badger Hollow near Clyde, WA	4.16	12/23	1560	375.0	>100[d]	1955-1974	*	*	
14017600	Touchet River at Touchet, WA	747	12/22	11500	15.4	1.22[e]	1941-	13300	17.8	1949
D. Other Walla Walla River Basin										
14010000	South Fork Walla Walla River near Milton, OR	63	01/29	2530	40.2	23[g]	1903 1906-1917 1931-1970	-	-	1931 2430 cfs in 1946

Table 2.3 (continued) Observed Peak Discharges During Storms of December, 1964 and January, 1965, and Other Extreme Events Streams of Southeastern Washington and Nearby Areas[a]

USGS Station Number	Stream and Location	Drainage Area (mi^2)	Maximum, Dec. 1964 and Jan. 1965: Date	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Estimated Recurrence[b] (yr)	High-Flow Gaging History: Period of Record[c]	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Remarks
14011000	North Fork Walla Walla River near Milton, OR	42	01/30	2050	48.8	35[g]	- -	*	*	1980 cfs in 1946
14013000	Mill Creek near Walla Walla, WA	59.6	01/29	3680	61.7	50[g]	1913-1917 1938-pres	*	*	2610 cfs in 1945
14013500	Blue Creek near Walla Walla, WA	17.0	01/28	716	42.1	26[g]	1939-pres	725	42.6	1945
14013600	Mill Creek, below Blue Creek, near Walla Walla, WA	91	01/29	3270	35.9	-	1962-pres	*	*	703 cfs in 1964
14015000	Mill Creek at Walla Walla, WA	95.7	12/23	2400	25.1	-	1941-1970	2760	28.8	1945
14016000	Dry Creek near Walla Walla, WA	48.4	12/22	1040	21.5	27[g]	1949-pres	3340	69.0	1949
14016050	Dry Creek, near mouth at Lowden, WA	246	12/22	10800	43.8	-	-			
14016100	Pine Creek near Touchet, WA	170	12/22	3770	22.2	-	none			
14018500	Walla Walla River near Touchet, WA	1657	12/22	33410	20.2	1.92[e]	1951-pres	*	*	16300 cfs in 1952
14019100	Tributary to Walla Walla River near Wallula, WA	0.80	12/22	320	400	-	1955-1976	*	*	6.0 cfs in 1958
II. Selected Streams in Nearby Areas										
A. Palouse Basin and Adjacent Areas										
13341500	Potlatch River at Kendrick, ID	425	01/29	16000	37.65	1.03[e]	1946-pres	*	*	13000 cfs in 1948
13341600	Arrow Gulch at Arrow, ID	2.80	12/23 or 24	220	78.6	-	1961-pres	*	*	150 cfs in 1963
13341800	Lapwai Creek near Culdesac, ID	37.9	01/29	2190	57.8	-	none			
13342400	Lapwai Creek near Lapwai, ID	235	01/29	4380	18.6	-	1948-pres	*	*	3800 cfs in 1948

Table 2.3. (continued) Observed Peak Discharges During Storms of December, 1964 and January, 1965, and Other Extreme Events Streams of Southeastern Washington and Nearby Areas[a]

			Maximum, Dec. 1964 and Jan. 1965				High-Flow Gaging History			
USGS Station Number	Stream and Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Estimated Recurrence[b] (yr)	Period of Record[c]	Peak Discharge (cfs)	Peak Unit Runoff (cfs/mi^2)	Remarks
13346100	Palouse River at Colfax, WA	497	12/24	8510	17.1	4[g]	1955-pres	*	*	8030 cfs in 1963
13348000	South Fork Palouse River at Pullman, WA	132	12/23	2610	19.8	19[g]	1934-1942 1959-pres	5000	37.9	1948 2160 in 1963
13348500	Missouri Flat Creek at Pullman, WA	27.1	12/23	1080	39.8	1.11[e]	1934-1940 1960-pres	1500	55.4	1948 1080 cfs in 1963
13349310	Palouse River at Winona, WA	986	01/29	9900	10.0	-	none			
13349320	Rebel Flat Creek at Winona, WA	75	01/28	840	11.2	3.39[e]	none			
13349350	Hardman Draw at Plaza, WA	1.64	01/29	92	56.1	7[d]	1955-1974	1780	1100	1957
13351000	Palouse River at Hooper, WA	2500	01/30	17100	6.8	8[d]	1897-1916 1951-pres	33500	13.4	1963 23100 cfs in 1979
B.	Grande Ronde River Basin and Adjacent Areas									
13292000	Imnaha River at Imnaha, OR	622	01/31	1330	2.1	<2[g]	1928-pres	6650	10.7	1957
13323500	Grande Ronde River near Elgin, OR	1250	02/02	6480	5.2	<2[g]	1948 1955-pres	-	-	5690 in 1948
13330000	Lostine River near Lostine, OR	70.9	12/23	442	6.2	<2[g]	1912-1915 1925-pres	2530	35.7	1913
13332500	Grande Ronde River at Rondowa, OR	2555	01/30	24700	9.7	22[g]	1926-pres	*	*	19900 cfs in 1948
13333000	Grande Ronde River at Troy, OR	3275	12/23	42200	12.9	1.08[e]	1944-pres	*	*	30000 cfs in 1946

[a]Developed from various U.S. Geological Survey documents.

[b]Estimated recurrence of peak flow, in years, and presented solely to aid in general comparisons between streams. The meaning of and best procedures for estimating recurrence in southeastern Washington remain unresolved (see text).

[c]Period for which data on all significant flood events would have been collected.

[d]Based on interpolation from estimated recurrence curves for this station developed by USGS (Haushild, 1979).

[e]Ratio of peak discharge to the estimated 50-year storm, based on data available in the late-1960's, published in Waananen and others, 1971.

[f]Based on log Pearson type III distribution of recurrences for period of record through 1979.

[g]Presented as published by USGS in Waananaen and others, 1971.

*Storms of 1964-5 are largest observed during period of record.

because of many reports of changes in the river pre-dating the major flood events. Resolution and vertical control on both of these sets was adequate to good, and significantly better than the photos taken in July, 1964. Both sets were photographed in late-July or early-August of a year with runoff moderately below normal.

Methods. The river was divided into four sections for the purposes of this analysis:

1. Cummings Creek to Bridge 10, just upstream of Marengo.
2. Bridge 10 to Willow Creek.
3. Willow Creek to Pataha Creek.
4. Pataha Creek to the river mouth.

Within each section, we chose to study a continuous reach with a length of 4 to 6 miles. We felt that a relatively long, continuous stretch of channel would minimize bias due to any effects of tributaries, bedrock outcrops or the practices of any one or two individual ownerships. Study reaches were chosen largely on the basis of the quality of the aerial photography, to avoid places where heavy shadows obscured the channel. The analysis eventually included 40 to 50 percent of the first, second and fourth sections of the river and virtually all of the section between Willow and Pataha Creeks.

Using stereomagnifiers, the channel pattern, dikes and revetments, vegetation, and land use on the valley bottoms were mapped on acetate overlays. The scale of the aerial photos enabled individual trees or small buildings to be distinguished.

Horizontal register was provided by landmarks with maximum spacing of 300 yards. Short segments of two of the channel change maps are shown in Figure 2.1 and Figure 2.2. Both figures are photoreductions of the basic data used in the analysis.

Changes in the Channel Pattern. Maps of the active channels in both 1937 and 1978 were made from the aerial photographs. Active channels are the portions of the bed which convey moderately high flows, perhaps those typical of the peak snowmelt period. The active channel differs from the floodway, or the configuration of the channel at very high flows. It also differs from the late-summer channel critical to biologic activity in the river, which could not be consistently identified from the aerial photos.

The principal change in the channel is a major increase in the extent of braiding and related bar development. In the 1937 photographs, some braiding was evident, often immediately below tributary confluences or other localized disturbance. By 1978, almost half of the channel length was markedly braided, and this channel pattern was pervasive throughout the length of the river. In 1978, braiding was most developed at places where, in 1937, tightly-curved meanders were found.

Many changes in the character and pattern of a channel are not readily or systematically quantifiable. Those which could be established on a consistent basis are summarized in Table 2.4. The length of the river's main channel was shortened from 7 to 20 percent in the four study reaches. This represents a loss of about half of total channel sinuosity, the ratio of stream and valley lengths. Many of the bends and other irregularities of

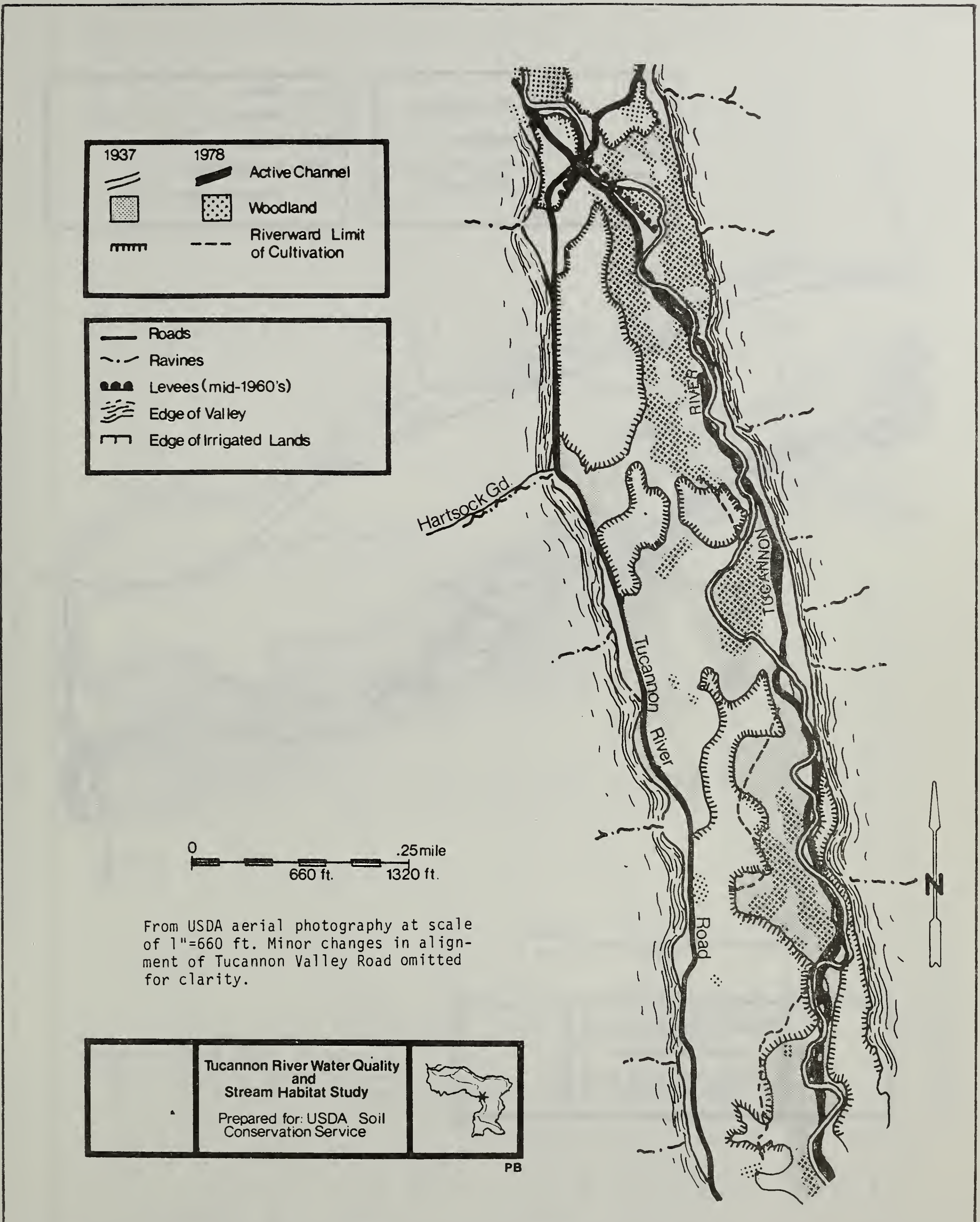

Figure 2.1. Changes in the Channel and Riparian Zone, 1937 to 1938, Tucannon River Below Tumalum Creek. Direction of flow is to the north.

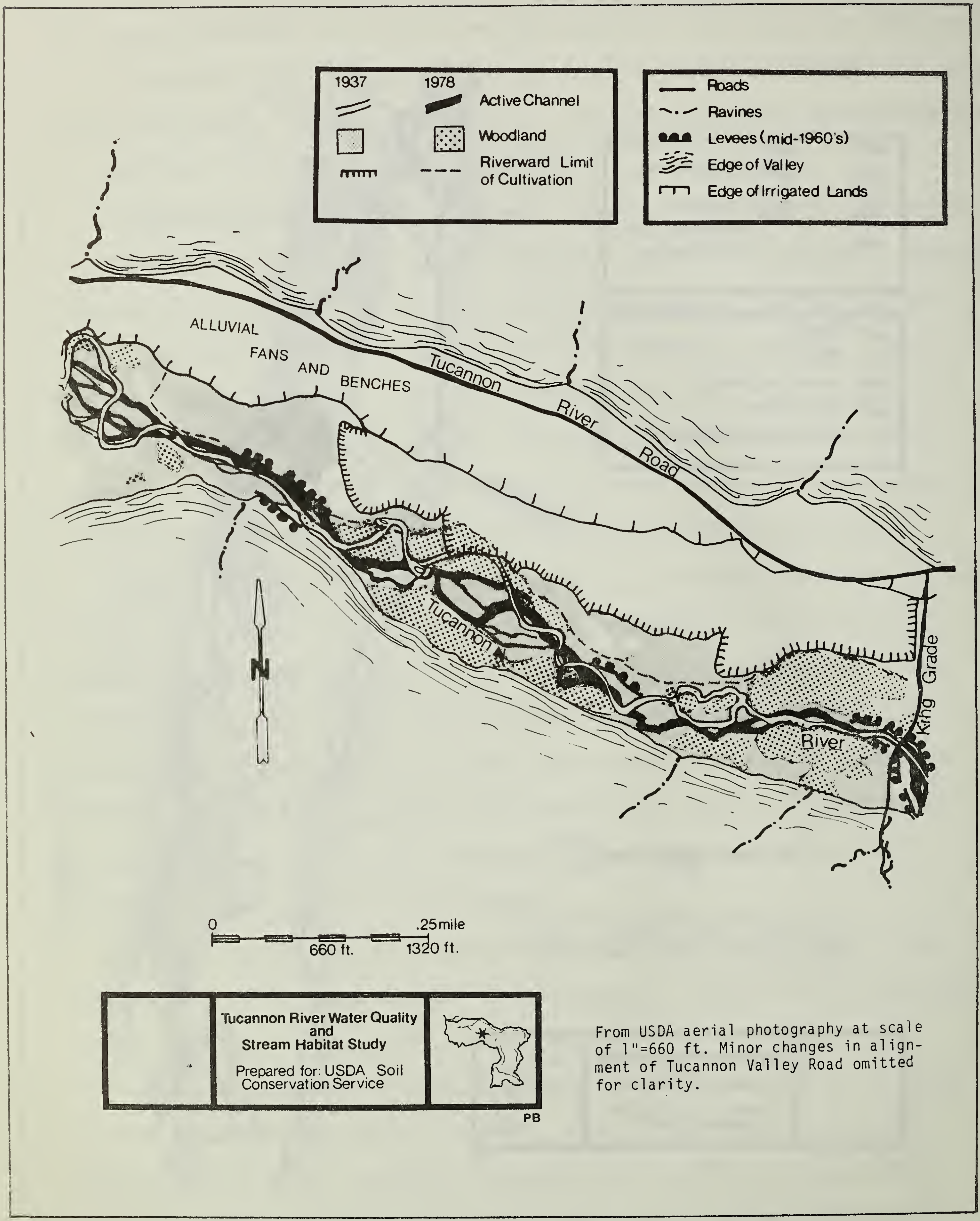

Figure 2.2. Changes in the Channel and Riparian Zone, 1937 to 1978, Tucannon River at King Grade Below Marengo. River flows to the northwest.

Table 2.4. Changes in Length of Main-Stem Channel[a/]
Selected Reaches of the Tucannon River, 1937-1978

	Reach and Sub-Reach[b/]	Length of Channel (mi) 1937	1978	Change[c/] %	Valley Length[d/] (mi)	Sinuosity[e/] 1937	1978
I.	Tumalum to Donohue's (total)	4.31	3.78	-12.3	3.57	1.21	1.06
	Tumalum Cr. to Bridge 14	.93	.66	-29.0	.63	1.09	1.04
	Bridge 14 to Bridge 13	1.61	1.48	- 8.9	1.43	1.12	1.03
	Bridge 13 to Bridge 12	1.20	1.15	4.4	1.08	1.11	1.06
	Bridge 12 to end of reach	.57	.49	-14.0	.43	1.32	1.14
II.	Marengo to Brines Rd. (total)	5.85	5.08	-13.2	4.55	1.29	1.12
	Near Marengo to Kings Grade	1.28	1.06	-17.2	.94	1.36	1.13
	Kings Grade to Secs. 5/6	1.39	1.16	-16.5	1.06	1.31	1.09
	Secs. 5/6 to Forked North Tributary	1.56	1.34	-14.1	1.14	1.37	1.18
	Forked North Tributary to Brines Rd.	1.62	1.52	- 6.2	1.41	1.15	1.07
III.	Highway 12 to Pataha Creek (total)	2.32	2.18	- 5.6	2.06	1.13	1.07
	Hwy 12 to Mom's Cafe	.62	0.61	- 1.6	.56	1.11	1.09
	Mom's Cafe to Pataha Creek	1.70	1.56	- 8.2	1.50	1.13	1.04
IV.	Pataha Creek to Smith Hollow (total)	4.21	3.48	-17.3	3.11	1.35	1.12
	Pataha Creek to Secs. 23/24	1.12	.86	-23.2	.78	1.44	1.10
	Secs. 23/24 to Secs. 22/23	1.25	1.06	-15.2	1.02	1.23	1.04
	Secs. 22/23 to Smith Hollow	1.84	1.56	-15.2	1.31	1.40	1.19

a/ Length of main low-flow channel, as determined from aerial photographs taken in the summers of 1937 and 1978 (nominal scale: 8 inches to the mile). Widest channel used when bifurcated or braided.

b/ As in Table 2.6

c/ Percentage longer (+) or shorter (-) in 1978 relative to 1937 length.

d/ Measured along the center-line of the valley

e/ $\text{Sinuosity} = \frac{\text{length of main-stem channel}}{\text{length of valley}}$

the channel--which provided much of the quieter water for salmonid rearing--were lost during this period. Similarly, a decrease of channel length and curvature necessarily involves an increase in channel gradient, and a probable increase in the mean flow velocity.* The magnitude of these changes is large. Very few streams are known to have undergone a similar decrease in length and increase in slope.

To what degree are these changes related to the extreme floods of December 1964 and January 1965? We reviewed the 1954 and 1964 aerial photographs in each study reach. There was very little change evident in the channel pattern above Marengo prior to 1964. Below Marengo and above Pataha Creek, most of the visible changes in pattern occurred between 1964 and 1978, especially above Willow Creek. Slightly less than half of the channel changes below Pataha Creek were observed during the most recent period. An estimate of the proportional changes occurring during each of the intervals might reasonably be made for this reach as follows:

1937-1954	40% of the overall net change
1954-1964	20% of the overall net change
1964-1978	40% of the overall net change.

It is likely that much of the altered channel form during the most recent period is associated with the floods of the 1965 water year. There were, however, other major geomorphic events during this

* Use of main-stem channel lengths in these computations results in an overstatement of the extent of change. For example, much of the present usable habitat is found in secondary channels. We believe, however, that this overstatement is small relative to the magnitude of change.

interval. The effects of the various floods cannot be distinguished without additional information.

Changes in Riparian Zone Character. On the acetate overlays, we mapped the areas of the valley flat occupied by fields (plus orchards and farmsteads), riparian woodland, active channel, and open area adjacent to the channel--primarily gravel bars and non-irrigated pasture. Most areas mapped as fields had been previously outlined and typed as to crop by local SCS staff at various times in the past. These areas were then planimetered by sub-reaches, generally of 1 to 1.5 miles in length. The results of this analysis are shown in Table 2.5.

The area of riparian woodland decreased by an average of one-third to one-half in the four reaches. Much or most of this change is apparently related to major floods in the post-1964 period. This is true especially of two reaches above Willow Creek. In all but the upstream-most study reach, much of the loss in riparian woodland can be related to encroachment of other land uses, principally irrigated fields and pasture. The proportion of the valley flat occupied by open areas increased in all four reaches. Most of these areas experience seasonal or occasional flooding, at least to a degree that preclude their cultivation.

Changes in Bank Character. Analysis of temperature data collected during the 1960's (Chapter 5) suggest that the Tucannon River was significantly warmer in the summer months following the floods of December 1964 and January 1965. Kelley and Li, in a companion report, find that summer water temperatures are still a principal constraint to use of the Tucannon River by salmonids.

Table 2.5. Changes in Riparian Zone Character.

Tucannon River 1937 - 1978[a]

Reach and Subreach[b]	Riparian Zone Character[c]	Area (acres) in Given Year		Change[d] (%)
		1937	1978	
I. TUMALUM TO DONOHUE'S				
1) Tumalum Creek to Bridge 14	wooded	9.4	3.4	-63.8
	open	11.5	23.4	+103.5
	field	55.0	58.6	+6.5
	channel	7.0	6.6	-5.7
2) Bridge 14 to Bridge 13	wooded	50.0	37.9	-24.2
	open	18.9	19.4	+2.6
	field	72.9	85.3	+17.0
	channel	8.3	5.2	-37.4
3) Bridge 13 to Bridge 12	wooded	20.3	13.8	-32.1
	open	2.3	5.5	+139.1
	field	17.1	28.1	+64.3
	channel	5.2	5.2	0.0
4) Bridge 12 to Donahue's	wooded	10.1	3.9	-61.4
	open	1.8	7.2	+300.0
	field	11.7	12.8	+9.4
	channel	8.4	7.8	-7.6
REACH TOTAL	wooded	89.8	59.0	-34.0
	open	34.5	55.5	+61.0
	field	156.7	184.8	+18.0
	channel	28.9	24.8	-14.0

a/ Determined from area photographs taken September 27, 1937 and July 28, 1978. (Nominal scale 8 inches to the mile.)

b/ For reach divisions see Table

c/ Wooded areas are those with mature arboreal vegetation of greater than 50 percent cover; open areas include gravel bars and non-irrigated pasture, and areas with small riparian shrubs, trees, and herbaceous plants; field describes irrigated pasture and areas under cultivation; and channel refers to acreage defined by the channel course.

d/ % change in acreage from 1937 to 1978.

Table 2.5 (continued). Changes in Riparian Zone Character.

Tucannon River 1937 - 1978[a]

Reach and Subreach[b]	Riparian Zone Character[c]	Area (acres) in Given Year		Change[d] (%)
		1937	1978	
II. MARENGO TO BRINES ROAD				
1) Near Marengo to Kings Grade	wooded	45.8	28.0	-38.9
	open	13.3	8.8	-33.9
	field	57.0	82.7	+45.1
	channel	9.5	8.3	-12.6
2) Kings Grade to Secs. 5/6	wooded	53.4	28.9	-45.9
	open	5.2	14.8	+184.6
	field	39.8	57.7	+44.9
	channel	10.5	7.8	-25.7
3) Secs. 5/6 to Forked North Tributary	wooded	33.6	17.5	-47.9
	open	27.3	30.1	+10.3
	field	40.9	54.1	+32.3
	channel	12.3	9.8	-20.3
4) Forked North Tributary to Brines Road	wooded	32.5	8.6	-73.5
	open	3.8	8.8	+131.5
	field	55.8	46.3	+36.7
	channel	11.6	1.4	-1.8
REACH TOTAL	wooded	165.3	83.0	-49.8
	open	49.6	62.5	+26.0
	field	193.5	270.8	+39.9
	channel	43.9	37.3	-15.1

a/ Determined from area photographs taken September 27, 1937 and July 28, 1978. (Nominal scale 8 inches to the mile.)

b/ For reach divisions see Table 2.6

c/ Wooded areas are those with mature arboreal vegetation of greater than 50 percent cover; open areas include gravel bars and non-irrigated pasture, and areas with small riparian shrubs, trees, and herbaceous plants; field describes irrigated pasture and areas under cultivation; and channel refers to acreage defined by the channel course.

d/ % change in acreage from 1937 to 1978.

Table 2.5 (continued). Changes in Riparian Zone Character.

Tucannon River 1937 - 1978[a/]

Reach and Subreach[b/]	Riparian Zone Character[c/]	Area (acres) in Given Year		Change[d/] (%)
		1937	1978	
III. HIGHWAY 12 TO PATAHA CREEK				
1) Highway 12 to "Mom's Cafe"	wooded	4.5	4.6	+2.2
	open	5.3	5.6	+5.6
	field	26.1	26.4	+1.2
	channel	2.0	2.2	+10.0
2) "Mom's Cafe" to Krouse Bridge	wooded	22.0	6.6	-70.0
	open	12.8	8.6	-32.8
	field	24.5	17.5	-28.6
	channel	1.9	2.1	+10.5
3) Krouse Bridge to Pataha Creek	wooded	30.2	19.2	-36.5
	open	16.3	23.9	+46.6
	field	49.2	50.6	+2.8
	channel	5.2	6.1	+17.3
REACH TOTAL	wooded	56.7	30.4	-46.4
	open	34.4	38.1	+10.7
	field	59.8	94.5	+58.0
	channel	9.1	10.4	+14.3

a/ Determined from area photographs taken September 27, 1937 and July 28, 1978. (Nominal scale 8 inches to the mile.)

b/ For reach divisions see Table

c/ Wooded areas are those with mature arboreal vegetation of greater than 50 percent cover; open areas include gravel bars and non-irrigated pasture, and areas with small riparian shrubs, trees, and herbaceous plants; field describes irrigated pasture and areas under cultivation; and channel refers to acreage defined by the channel course.

d/ % change in acreage from 1937 to 1978.

Table 2.5 (continued). Changes in Riparian Zone Character.

Tucannon River 1937 - 1978[a/]

Reach and Subreach[b/]	Riparian Zone Character[c/]	Area (acres) in Given Year		Change[d/] (%)
		1937	1978	
IV. PATAHA CREEK TO SMITH HOLLOW				
1) Pataha Creek to Secs. 23/24	wooded	21.4	13.4	-34.4
	open	11.3	15.9	+40.7
	field	35.2	38.3	+8.8
	channel	4.7	4.1	-12.8
2) Secs. 23/24 to Secs. 22/23	wooded	13.6	1.9	-86.0
	open	18.1	23.9	+32.0
	field	8.0	20.6	+157.5
	channel	8.0	6.7	-16.2
3) Secs. 22/23 to Smith Hollow	wooded	28.6	19.2	-32.9
	open	57.0	49.5	-13.2
	field	0.6	13.3	+2116.7
	channel	10.0	8.4	-16.0
REACH TOTAL	wooded	63.6	34.5	-45.8
	open	86.4	89.3	+3.4
	field	43.8	72.2	+64.8
	channel	22.7	19.2	-15.4

a/ Determined from area photographs taken September 27, 1937 and July 28, 1978. (Nominal scale 8 inches to the mile.)

b/ For reach divisions see Table 2.6

c/ Wooded areas are those with mature arboreal vegetation of greater than 50 percent cover; open areas include gravel bars and non-irrigated pasture, and areas with small riparian shrubs, trees, and herbaceous plants; field describes irrigated pasture and areas under cultivation; and channel refers to acreage defined by the channel course.

d/ % change in acreage from 1937 to 1978.

They further determine, by use of a calibrated temperature model. that bank shading is a dominant influence on water temperatures. One critical aspect of changes in the Tucannon channel and riparian system, then, is the extent to which shaded banks have been becoming more or less prevalent. Other changes in bank character also affect habitat values.

Using a map wheel, we determined the length in each reach of the banks of major channels which were open, wooded, cut into the balley sides, or have been diked or leveed.* These measurements and the extent of change over the 41-year period, are described in Table 2.6.

Wooded banks were much less common in 1978 than in 1937. Conversely, open banks became prevalent in all four reaches. These changes are most marked in the reach above Marengo, where seven-eighths of the wooded banks were lost, most of which occurred since 1964. This is the only reach presently capable of supporting salmonids during the late-summer months; other reaches are too warm.

Banks of the river in all four reaches have probably become inherently less stable as a result of these changes. In south-eastern Washington, wooded banks are relatively stable, much more so than grassy or gravelly banks. Leveed portions of the channel have increased, but not to an offsetting degree.

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* Channelization is further described and discussed in the next section of this chapter.

Table 2.6. Changes in Bank Character
Selected Reaches of the Tucannon River
1937 - 1978[a]

Reach	Bank Character[b]	Length (mi) in Given Year[c] 1937	1978	Change[d] (%)
I. Tumalum Creek to Donohue's				
Tumalum Creek to Bridge 14				
	Wooded	.42	.04	-90.5
	Open	.62	.89	+43.5
	Rockbank	.02	.10	+400.
	Leveed	0	.13	--
Bridge 14 to Bridge 13				
	Wooded	2.39	.30	-87.4
	Open	.78	2.00	+156.4
	Rockbank	.04	.05	+25.0
	Leveed	0	.32	--
Bridge 13 to Bridge 12				
	Wooded	1.19	.20	-83.2
	Open	.70	1.45	+107.1
	Rockbank	.27	.41	+51.9
	Leveed	0	.10	--
Bridge 12 to Donohue's [e]				
	Wooded	.70	.03	-95.7
	Open	.19	.62	+226.3
	Rockbank	.10	.19	+90.0
	Leveed	0	0	--
REACH TOTAL				
	Wooded	4.70	.57	-87.9
	Open	2.29	4.96	+116.7
	Rockbank	.43	.75	+74.4
	Leveed	0	.45	--
II. Marengo to Brines Road				
Near-Marengo[f] to Kings Grade				
	Wooded	1.56	.49	-68.6
	Open	.54	1.60	+196.3
	Rockbank	.19	0	100.0
	Leveed	0	.05	--
Kings Grade to Secs. 5 6[g]				
	Wooded	2.24	.70	-68.8
	Open	.26	1.45	+457.7
	Rockbank	.06	.06	0
	Leveed	0	.26	--
Secs. 5/6 to Forked North Tributary				
	Wooded	1.14	.33	-71.1
	Open	1.95	2.08	+6.6
	Rockbank	.15	.26	+73.3
	Leveed	0	.13	--
Forked North Tributary to Brines Rd.				
	Wooded	.96	.31	-67.7
	Open	1.81	1.38	-23.8
	Rockbank	.94	.84	-10.6
	Leveed	0	.44	--
REACH TOTAL				
	Wooded	5.90	1.83	-69.0
	Open	4.56	6.51	+42.8
	Rockbank	1.34	1.16	-13.4
	Leveed	0	.88	--

Table 2.6.Continued.
Changes in Bank Character
Selected Reaches of the Tucannon River
1937 - 1978[a/]

Reach	Bank Character[b/]	Length (mi) in Given Year[c/] 1937	1978	Change[d/] (%)
III. Highway 12 to Pataha Creek				
Highway 12 to "Mom's Cafe"				
	Wooded	.24	.26	+8.3
	Open	.84	.51	-40.3
	Rockbank	.25	.25	0.0
	Leveed	0	.25	--
"Mom's Cafe" to Krouse Bridge				
	Wooded	1.75	.61	-65.0
	Open	.88	1.50	+70.4
	Rockbank	.65	.55	-15.4
	Leveed	0	.39	--
Krouse Bridge to Pataha Creek				
	Wooded	.91	.19	-79.0
	Open	.85	.86	+1.2
	Rockbank	.34	.62	+82.4
	Leveed	0	.39	--
REACH TOTAL				
	Wooded	2.90	1.06	-63.0
	Open	2.57	2.87	+11.7
	Rockbank	1.24	1.42	+14.5
	Leveed	0	1.03	--
IV. Pataha Creek to Smith Hollow				
Pataha Creek to Secs. 23/24[h]				
	Wooded	.52	.29	-48.1
	Open	1.05	.84	-20.0
	Rockbank	0	0	+ 0.0
	Leveed j/	.25	.41	+64.0
Secs. 23/24 to Secs. 22/23[i]				
	Wooded	.63	.19	-69.8
	Open	1.95	1.51	-22.6
	Rockbank	.02	.05	+150.0
	Leveed j/	.42	.53	+26.2
Secs. 22/23 to Smith Hollow				
	Wooded	.33	.26	-21.2
	Open	3.14	2.30	-26.7
	Rockbank	.18	.16	-11.1
	Leveed	.25	.30	+20.0
REACH TOTAL				
	Wooded	1.48	.72	-52.0
	Open	6.14	4.65	-22.8
	Rockbank	.20	.21	+ 5.0
	Leveed	.92	1.24	+34.7

a/ Determined from aerial photographs taken September 27, 1937 and July 28, 1978, printed at nominal scale of 1:7920 (8 inches to the mile).

b/ Wooded areas are those with mature arboreal vegetation of greater than 50 percent cover; open areas include gravel bars, grassland and non-irrigated pasture, and areas with small riparian shrubs, trees, and herbaceous plants; rockbank describes segments in which the stream has cut into the bedrock walls of the valley and/or the related talus slopes; leveed banks are rirapped dikes, roads, or railroad beds.

c/ Total of the length of each bank of the main-stem channel. Each mile of channel has two miles of banks.

d/ Increase (+) or decrease (-) in 1978 relative to 1937

e/ Downstream end of reach is at a line joining the midpoints of Secs. 30 and 31, T11N, R41E.

f/ Section line between Secs. 9 and 10, T11N, R40E.

g/ Section line between Secs. 5 and 6, T11N, R40E.

h/ Section line between Secs. 23 and 24, T12N, R38E.

i/ Section line between Secs. 22 and 23, T12N, R38E.

j/ For 1937, leveed banks refer to where the stream flowed against the riprapped railroad grade.

Channelization of the Tucannon River. One result of the 1964, 1965, and 1969 floods was a variety of imposed changes in the course of the river. The channel is presently constrained by a variety of levees and revetments, road and railroad causeways, bulldozed dikes, bridges, small groins and log racks. The nature and distribution of these control structures are discussed below; the potential implications for habitat conditions and future flood hydrology are discussed in a later section.

Revetments: Rip-rapped levees emplaced on the Tucannon River prior to the floods of the 1960's were apparently limited to those protecting the community of Starbuck. Additionally, short reaches immediately above and below several key bridges had been channelized with revetments. During the late-1960's, short, disconnected revetment segments were constructed from above Camp Wooten to below Powers Road. Construction was sponsored or directed by the U.S. Army Corps of Engineers, the U.S.D.A. Soil Conservation Service, Washington State Department of Game and Fish, the State's Department of Parks and Recreation, Washington State Department of Transportation, Columbia County, and by a number of families and individuals owning streamside property. Circumstances facilitated construction of these structures, which might otherwise have been too costly. First, failure of virtually all bridges at and above Marengo isolated the upper part of the watershed. This includes several isolated but important state and federal facilities, in addition to perhaps 10 to 15 homes. Secondly, suitable heavy equipment was available in abundance due to levee construction

in the Dayton area (1963-1966), development of Little Goose Dam, plus re-alignment of the road and railroad below Powers. Active riprap quarries were centrally situated near Starbuck and Marengo. Finally revetments were a nationally-preferred flood control approach during this period. Both technical advice and federal supports for these structures were made available.

Riprapped levees installed under the supervision of the Soil Conservation Service and the Army Corps may have approaches 40,000 lineal feet along the Tucannon River (Duane Scott, pers. comm.) Perhaps an additional 20,000 to 40,000 lineal feet were constructed by the state, the county, and private parties. Much of the construction post-dates the 1969 storms.

Dikes and Causeways: The principal valley-side dike along the Tucannon River is the riprapped railroad bed below Pataha Creek to the vicinity of Smith Hollow. The dike, initially constructed in the 1880's, prevents the river from cutting into the north valley wall, but does not otherwise constrain channel migration or bed form.

Each road or rail crossing of the Tucannon River consists of a bridge and causeway which usually extends the full width of the valley floor. These effectively stabilize the channel pattern for several hundred feet above and below the crossings. It is possible that these fixed reaches occurring every several miles of river contribute to maintenance of the braided channel form. Elsewhere, diminished channel stability below channelized reaches has been widely reported in gravel-bedded streams. It is not clear

how this question might be approached in the Tucannon River, or what realistic management alternatives are indicated.

<u>Discussion.</u> The changes reported by local residents are all those expected in a change from predominantly meandering to predominantly braided channel pattern. Braided streams are wider and steeper, and have beds that generally are less stable. They also have two other characteristics which strongly affect rearing habitat values in the Tucannon River. First, velocities tend to be much more uniform in a braided stream. There are few pockets of quiet water, other than those produced by boulders, rock outcrops or snags that are too large for transport. Quiet waters, such as those forming on the inside of bends or behind trees which fall in the stream, are rapidly filled with gravel, and are unavailable for use as rearing habitat. Secondly and similarly, braided streams have very few pools. There is a distinction between runs and riffles, but it is of much less extent or significance than the alternating deeps and shoals prevalent in meandering channels.

In Chapter 7, there is a detailed discussion of hydraulic and geomorphic factors favoring continued braided configuration in the Tucannon River. Development of braiding is traced to several natural and land use influences, principal among them:

1. The Tucannon River is unusually steep for a stream of its size, due perhaps in part to geologic forces related to uplift of the Blue Mountains.
2. Land uses, especially upland small-grain agriculture, result

in greater peak runoff during storm events.

3. Bank stability has diminished with loss of riparian forests, in part due to the effects of the extreme floods and also to encroachment from other land uses.

Braiding is one form of hydraulic adjustment which may be expected in steep channels receiving greater storm runoff and with banks of diminishing stability. Other factors also have influenced the direction of hydraulic adjustment.

As a result of the predominant braided condition, the channel is wider, the bed is less stable, and pools are rare or poorly-developed. Additionally, the river is faster and warmer than in previous years, and the bed surface is more uniform. These changes are discussed in subsequent chapters, particularly Chapter 7.

Incision of Pataha Creek.

Finally, the differences in the character of the Tucannon River and Pataha Creek are noteworthy, and shed some light on the importance of bank stability in adjustment to the present runoff regimen in the watershed.

Pataha Creek is presently incised deeply into the valley floor. Incision is continuous from the Sweeney Gulch area (above Pomeroy) to the mouth of the creek. Typically, the bed is 10 to 15 feet below the valley flat in the upper half of the incised reach, and 20 to 25 feet downstream from the vicinity of Dodge Junction.

The depth of incision presently is limited by resistant rock occuring in the channel. Basalt outcrops are visible in the bed at numerous points throughout the incised reaches, most closely-spaced upstream of Pataha City and downstream of Archer Road.

Elsewhere, the bed is cut into a dense, cohesive, clay-rich alluvial gravel unit which is observed above the basalt, this unit forms the banks of the stream even in rock-cut reaches.

The incised channel is narrow, bounded by near-vertical walls. At its base the entrenched cut is usually only slightly wider than the active channel width at moderately high flows (bankfull stage). Bottom widths are typically 20 to 40 feet near Pataha City, increasing to 30 to 50 feet near the mouth; locally greater widths occur over short distances, especially near tributary confluences.

Longitudinal Slope. Although the incised channel of Pataha Creek is more conspicuous, one of the most unusual features of the Tucannon River's major tributary is its relatively slight slope. Lower Pataha Creek has an average slope of about 0.007 ft/ft, compared with an average of about 0.009 for the Tucannon River above the confluence or 0.007 for the Tucannon River from Pataha Creek to Starbuck. At a given elevation, the longitudinal slope of Pataha Creek is less than that of the Tucannon River up to an elevation of 2500 feet, or well into the Blue Mountains.

It is exceedingly unusual for a tributary to have a lower slope than that of the main stem in any large drainage net. In the case of Pataha Creek, the slope may be structurally constrained; the creek's east-west course, parallel to the regional slope, is anamalous, and probably was imposed by geologic influences. The gradient of the Tucannon River, interestingly, conforms to the same slope in the reach below Pataha Creek, where the river turns

abruptly westward to follow the same structural trend.

Adjustment to Present Runoff Regimen. Irrespective of origin, the unusually low gradient of Pataha Creek has probably inhibited development of a braided habit similar to that in the Tucannon River. The cohesive lower banks, cut into cemented gravels, also limit channel migration.

There is little question that Pataha Creek has been adjusting to the larger flood crests and sediment loads of the past 50 to 100 years. The adjustment has taken the form of a more incised, slightly wider channel. The lower slope, and the incised channel with cohesive lower banks, have imposed a different type of adjustment than that observed in the Tucannon River. Another contributing factor may be that the last extreme flood on Pataha Creek occurred in 1916; floodwaters reaching above the cohesive banks (generally 8 to 10 feet) might result in severe local erosion.

CHAPTER 3

STREAMFLOW

Streamflow reflects local weather and land use. It is a dominant and independent influence upon sediment transport and water quality. The discharge of water also directly affects many other aspects of the aquatic environment in the Tucannon River.

Measurement of Streamflow

Streamflow is generally monitored from records of the water level ("stage", or "gage height") of a stream. All computations are based on an empirical relation of discharge to stage, developed by measuring discharge through a range of stages with the water level being read from a fixed measuring rod, or "staff plate" (Figure 3.1). This procedure, standard worldwide, requires an assumption of no significant change in the configuration of the bed and banks; an altered configuration requires a new empirical relationship.

In the Tucannon watershed discharge was monitored at six gaging stations during water year 1980. Five gages were established for this study. No previous streamflow measurments had been made at these sites. Stage-discharge relationships were established at each station by measuring discharge over a broad range of flows. Figure 3.2 is an example of the stage-discharge relation for the gage on the Tucannon River at the Tucannon Hatchery. No distinguishable changes in the bed occurred at this location. This rating curve was used for the entire 1980 water year, and will continue to be in effect until the bed configuration is appreciably altered.

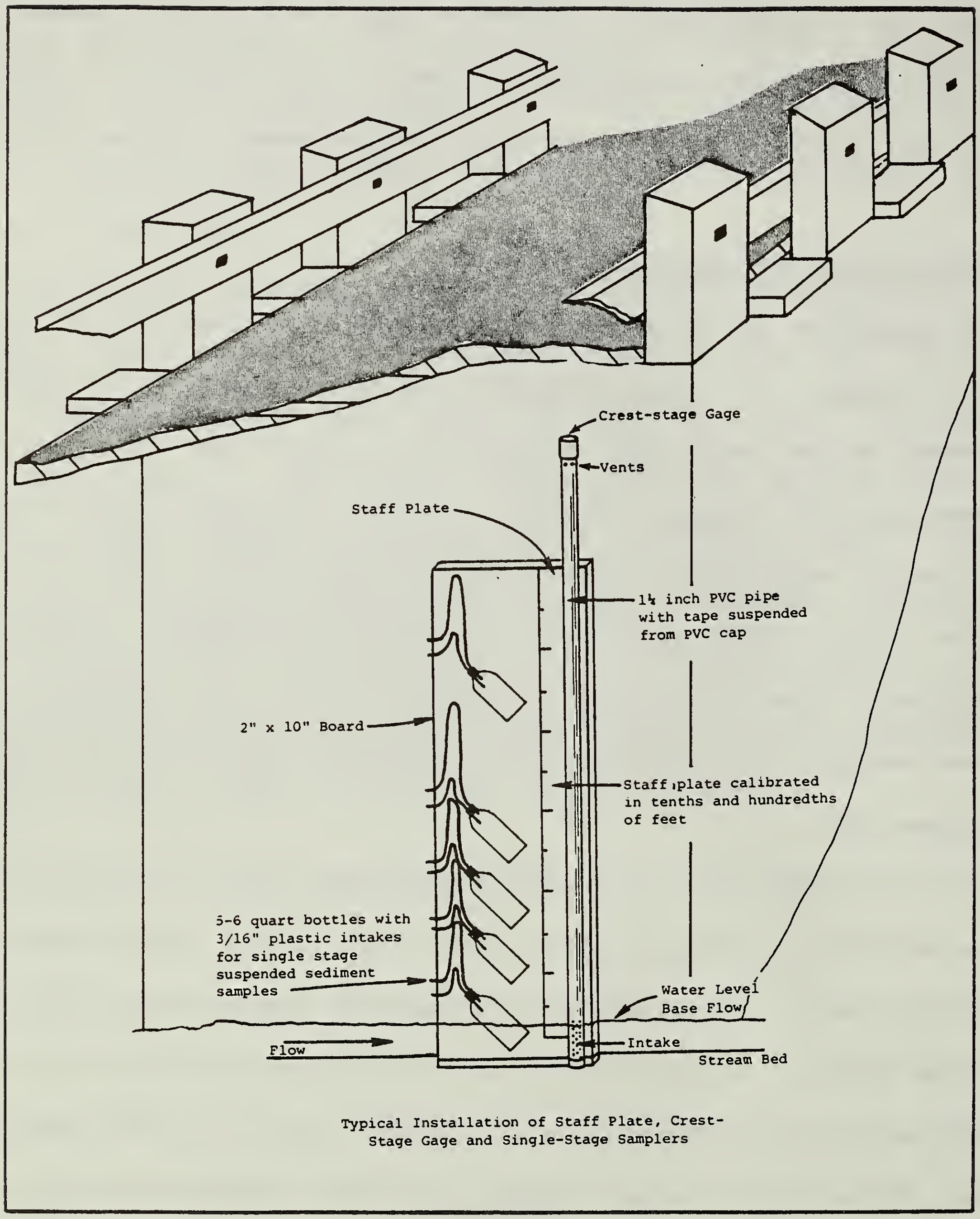


Figure 3.1. Staff Plate, Crest-Stage Gages, and Single-Stage Sampler Banks, Tucannon River Water Quality and Aquatic Habitat Study, 1979-1980. Single-stage samplers are discussed in Chapter 4.

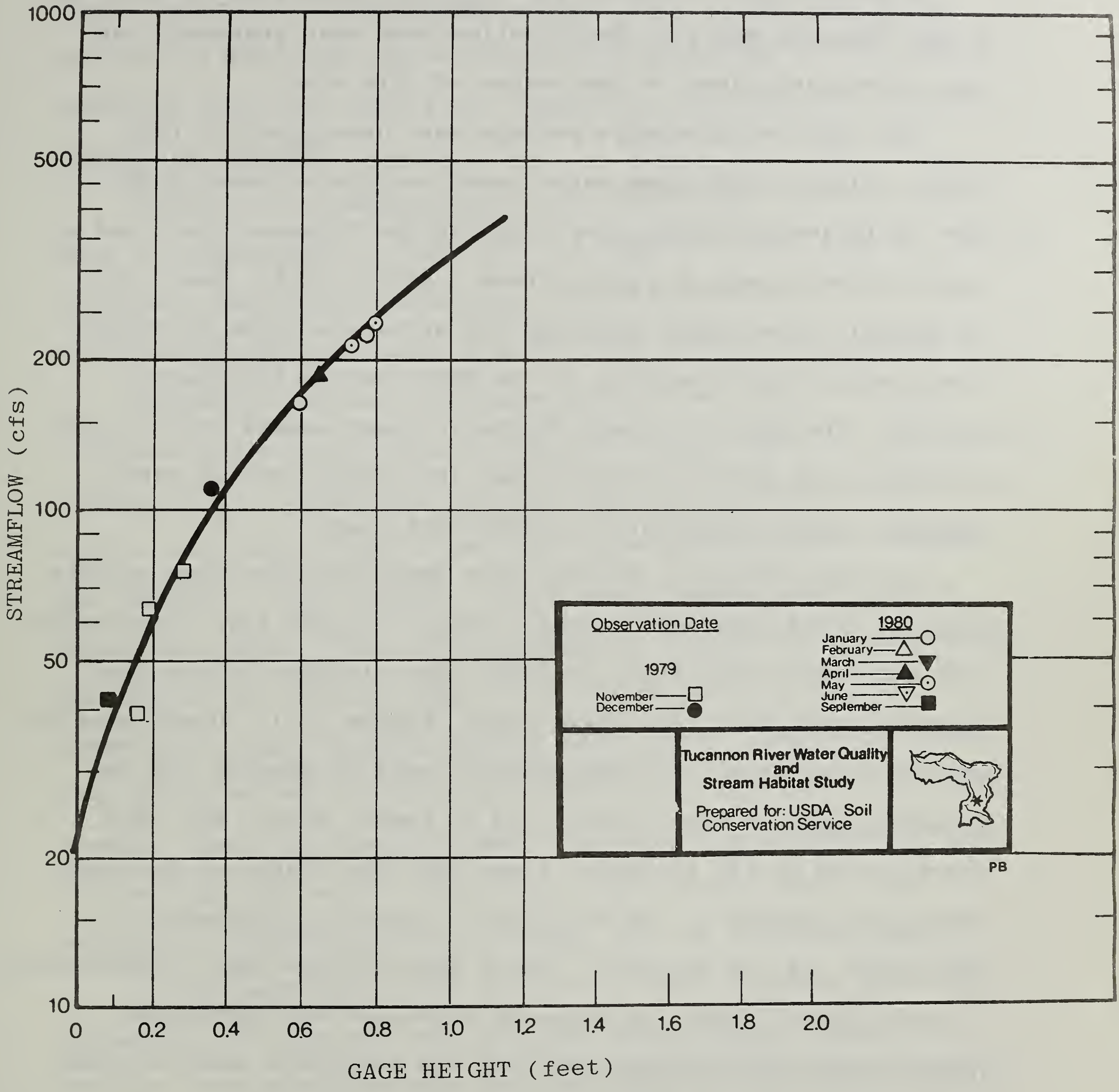


Figure 3.2. Stage-Discharge Relation, Tucannon River at Hatchery.

A sixth set of records, from the U.S. Geological Survey gage on the Tucannon River at Smith Hollow Road near Starbuck, was also extensively used in the course of this study.

Two types of discharge records were developed for this study. First, continuous water-level recorders (model A-35) were installed at the hatchery gage on the Tucannon River and at the Chard Road gage on Pataha Creek. Additionally, the U. S. Geological Survey staff provided the streamflow data developed from a water-level recorder at the Smith Hollow Road gaging station. The HEA staff made discharge measurements at this gage following each storm to verify that the present rating curve remained valid throughout the 1980 water year.

At other stations, records were developed from gage heights noted by field observers at each visit. In addition, flood peaks were determined from rings of burnt cork clinging to the tape measure inside the crest-stage gages (Figure 3.1). Discharges at each of these three stations--Pataha Creek at Pomeroy and the Tucannon River at Krouse Ranch and at Powers Road-- are thus known for 80 to 150 different times over the course of the year. These were related to the continuous records of discharge at Chard Road, at the hatchery, and at Smith Hollow Road, respectively. In practice, at least two separate relations were developed between each non-recording gage and its correlate, one for rainfall runoff and one or two for the snowmelt season.

The initial field observations of discharge were made during the second week in November 1979. Estimates of streamflow discharge

dating back to October 1, 1979, were synthesized from the discharge record at the USGS gage. Other gaps in the continuous discharge record were filled by cross-correlation of the three recording gages and from local temperature and rainfall records.

Streamflow, WY1980

Results of streamflow monitoring during the 1979-1980 water year are summarized in Table 3.1 and Figure 3.3 for each of the six stations. Mean daily discharge, instantaneous peak flows, and supplemental data are tabulated for each station in Appendix B.

Streamflow during 1980 was slightly lower than the mean for a 20-year period of record at the Smith Hollow Road gaging station (Figure 3.4). Runoff was below average during each of the winter months, and about 30 to 40 percent below normal during December and February. The rainfall runoff season began significantly later than usual. The first appreciable winter storm (exceeding 200 cfs at the Starbuck gage) occurred on January 12, about 5 weeks later than the mean initial storm date. The winter wheat crop may have been better-established than usual due to the late season. Runoff during the summer months was approximately equal to the long-term mean. Streamflow during other months was slightly-to-moderately below average for the 1959-1978 period.

In the portions of the watershed within the Blue Mountains, streamflow for the year was slightly above normal, based on a 40-year synthetic discharge history (Figure 3.5). Runoff during the peak rainfall and snowmelt months--the periods of maximum sediment movement--were from 10 to 60 percent above the synthetic long-term mean for the upper watershed. Figures 3.4 and 3.5, drawn at the same scale, allow comparison of the differences in the

Table 3.1. Summary of Streamflow, by Month, Tucannon River Watershed, WY 1980

Stream, Station	Drainage Area[b]	Mean Monthly Discharge (cfs)												Annual Average WY 1980
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Tucannon River at Fish Hatchery[c]	96	32.7	40.8	64.7	112.7	101.9	141.2	159.0	211.5	143.6	65.6	46.4	44.8	97.0
Tucannon River at Krouse Ranch	215	70.2	79.8	97.8	175.8	143.9	176.9	222.1	269.6	174.4	76.5	62.6	65.5	134.9
Pataha Creek at Pomeroy	77	3.9	4.8	10.6	23.1	18.9	22.8	25.7	24.8	15.2	8.8	5.4	2.9	12.9
Pataha Creek at Chard Road	146	4.3	5.1	11.8	37.6	27.4	31.9	34.2	24.3	15.2	9.3	5.8	3.4	17.2
Tucannon River at Smith Hollow Road[d]	431	78.5	92.3	116.3	224.0	185.6	223.0	265.3	293.7	185.5	85.8	66.4	70.0	157.5
Tucannon River at Powers Road	500	86.1	102.2	136.0	250.3	220.4	265.9	293.0	302.1	193.5	94.0	72.4	76.6	174.5

[a] Mean discharge for month, expressed in cubic feet per second (cfs);

[b] Drainage area in square miles.

[c] Measured flows, excluding constant flow of 10 cfs diverted upstream for the hatchery.

[d] Streamflow as computed by the U.S. Geological Survey.

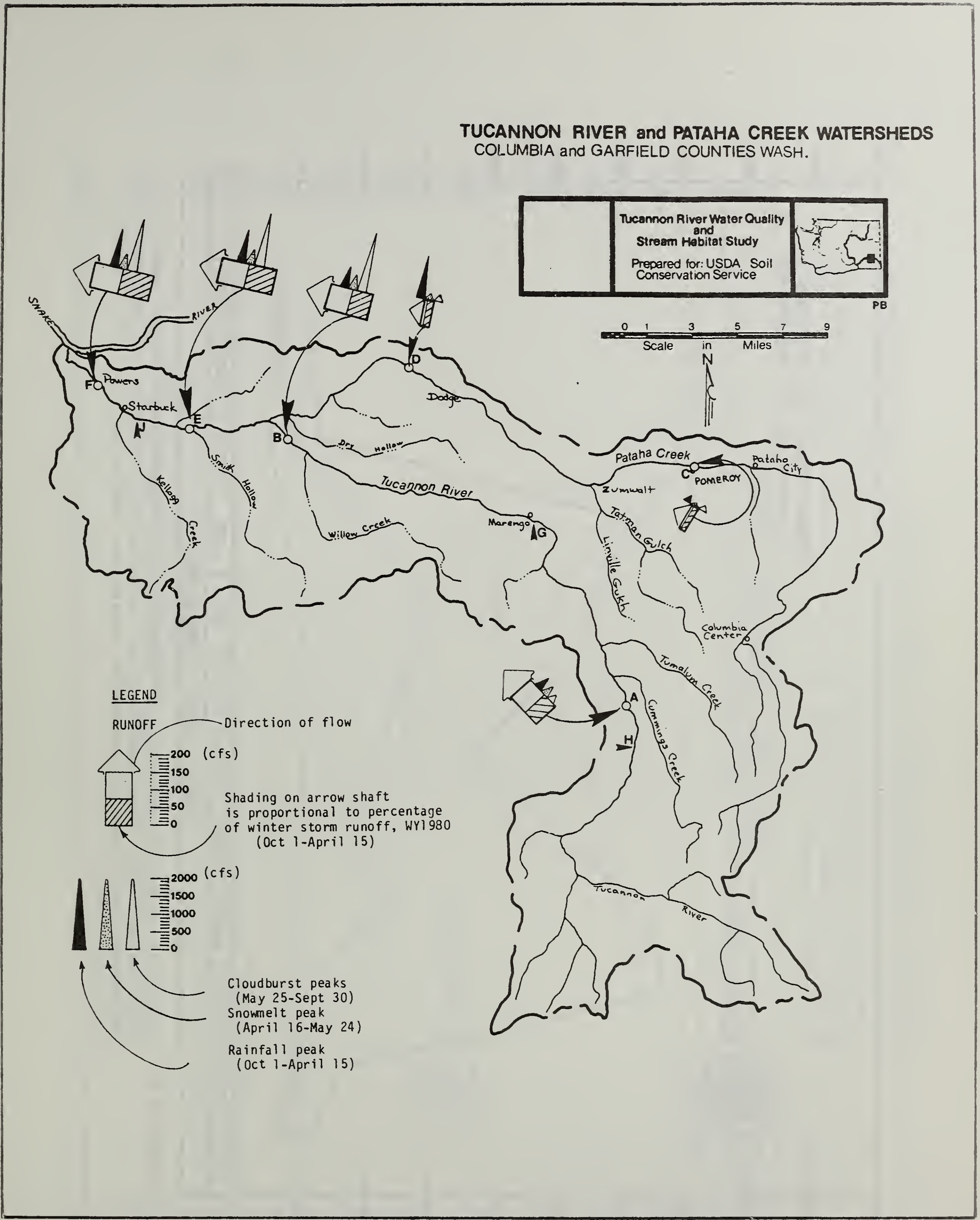


Figure 3.3. Summary of Streamflow and Peak Storm Runoff By Season, Tucannon Watershed, Water Year 1980.

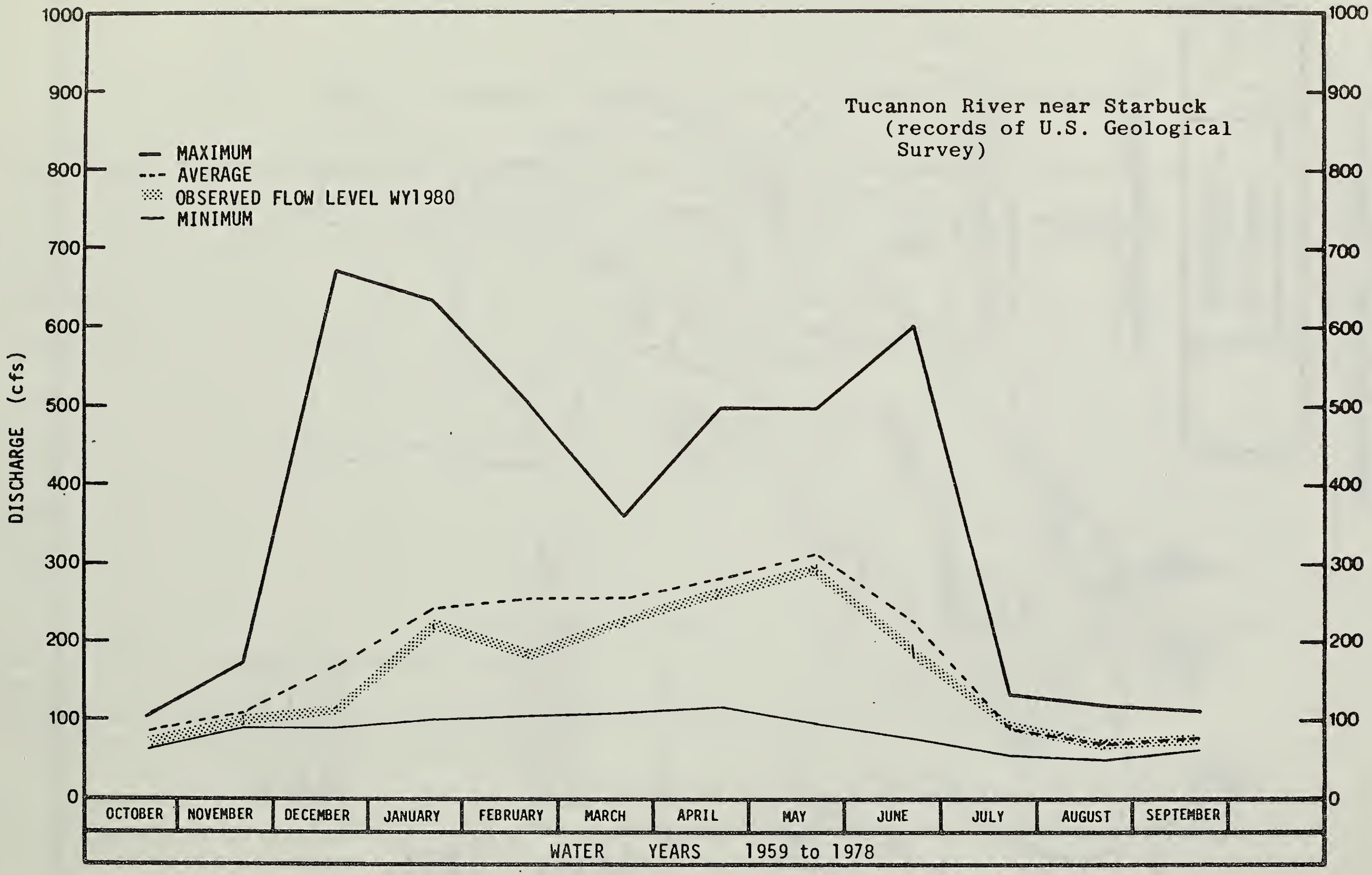


Figure 3.4. Variations in Streamflow by Month, Tucannon River Near Starbuck (water years 1959 through 1978). Mean monthly flows, and the observed range for each month, are compared with observed streamflow during the 1980 water year. See Appendix C for basic data.

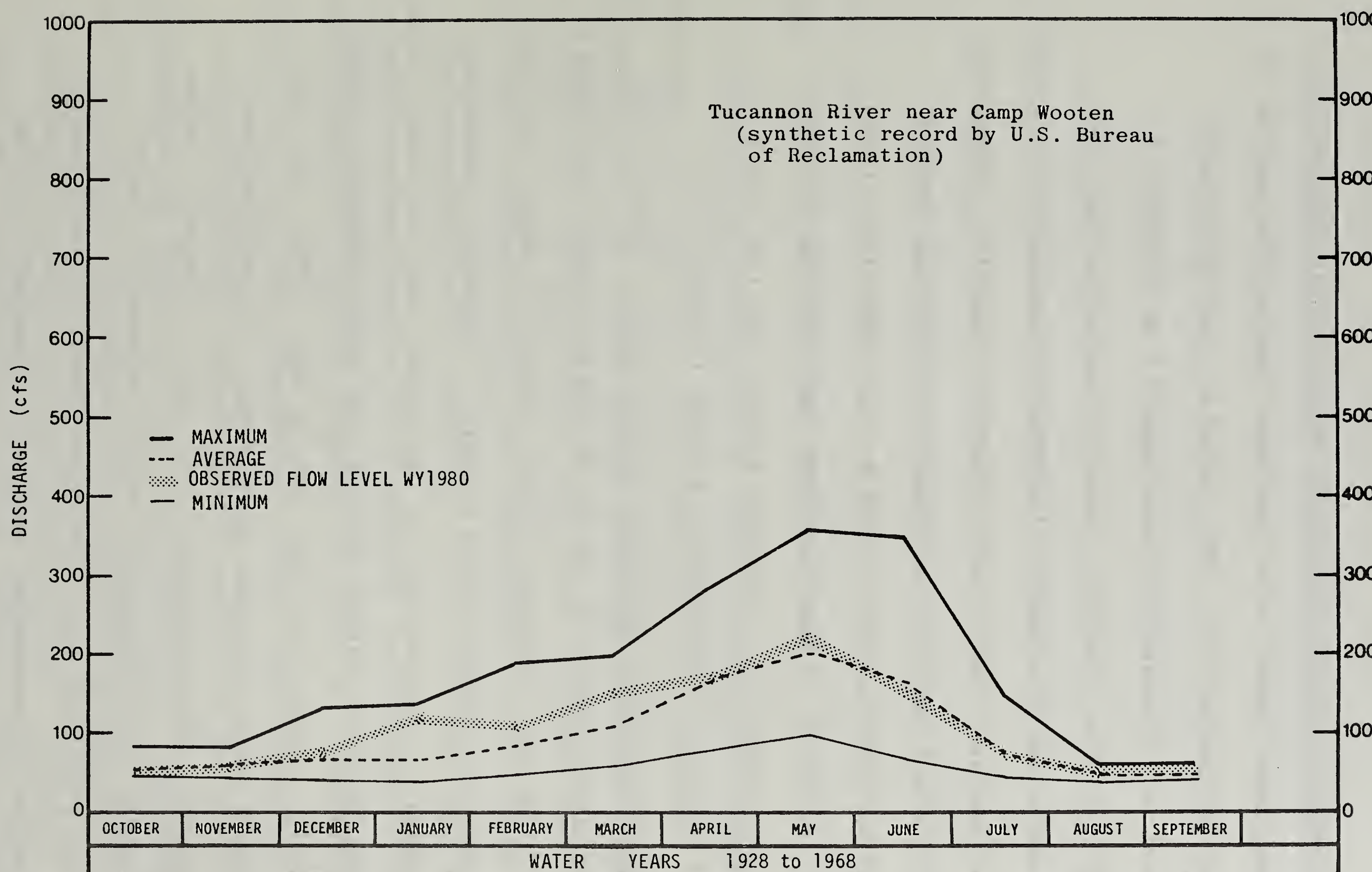


Figure 3.5. Variations in Estimated Streamflow by Month, Tucannon River at Proposed Dam Site Near Camp Wooten. Discharge at this site are almost identical to those at the hatchery gage, when the latter is adjusted for a 10.0 cfs diversion. Streamflow record synthesized by U.S. Bureau of Reclamation by correlation with the Grande Ronde River at Rondowa, Oregon, for the 1928 through 1968 water years. Observed monthly discharge at the hatchery gage, adjusted for diversions during WY1980 shown for comparison (dots).

runoff regimes of the upper and lower Tucannon watershed. Other anomalous runoff conditions during WY1980 included:

1. Winter storm runoff concentrated in a four-day period. Four separate peaks were observed during the period of January 12 through 15. The initial runoff episode followed an unusually heavy snowfall on January 8 through 10. Reportedly, snow accumulation was the greatest since the 1930's in Pomeroy and possibly since 1916 in Dayton. Subsequent storms generally increased in warmth and intensity during the four-day period, reportedly melting most snow to the 2500-foot level. Runoff observed at the hatchery gage during January, 1980, approached the maximum runoff for the month in the 40 years of synthesized record (Figure 3.5).
2. An unusually early snowmelt runoff peak. The spring peak occurred April 21 or 23 on Pataha Creek, and April 29 or 30 on the Tucannon River. Earlier peaks occur in less than 10 percent of all years. Seasonal recession of snowmelt occurred one to two weeks earlier than normal.
3. Limited rainfall runoff during the peak snowmelt period. Reportedly, more rain fell during May, 1980, than had previously been recorded during May in southeastern Washington. The combination of late, subnormal rainfall runoff with unusually turbid snowmelt runoff probably resulted in a disproportionately high relative amount of suspended sediment transport during the snowmelt season.

4. <u>Numerous cloudbursts throughout the summer.</u> At three stations, the instantaneous peak runoff for the year followed the Willow Creek cloudburst of June 16. Cloudbursts were the cause of instantaneous peak runoff only once before in the 22-year recent period of record at the U.S.G.S. gage near Starbuck.

The Pataha watershed above Chard Road contributed about 10 percent of the total streamflow at Powers Road, near the mouth of the Tucannon River. Overall, the Pataha watershed produced about 11.5 percent of the streamflow at Powers, when adjusted for additional square miles of drainage area below the Chard Road gage in the Delaney and Dry Hollow areas.

The area distribution of runoff within the Tucannon watershed was found, as expected, to be markedly non-uniform. Approximately 60 percent of the total runoff from the watershed originated in the 20 percent of the basin area above the hatchery gage. Most of the flow in Pataha Creek also originated in the upper portion of its watershed, above Pomeroy. Staff of the USDA Forest Service are making measurements of streamflow and sediment transport in Pataha Creek at Columbia Center, in part to determine the proportion of its flow originating within the mountains.

Observed instantaneous runoff peaks are presented for the six stations in Table 3.2 and in Figure 3.3. The most important runoff events of the water year occurred in mid-January and during the cloudburst season in late-May and June. Snowmelt peaks in the basin were substantially below normal. While overall runoff

Table 3.2. Observed Instantaneous Peak Discharges for Major Storms, Tucannon River Watershed, 1979-1980[a].

Station Location	Drainage Area (sq mi)	Peak Discharges															
		Winter Wet Season									Snowmelt				Thunderstorms		
		Dec 4-5	Jan[b] 12-13	Jan 13	Jan 14	Jan 14-15	Jan 17	Jan 18	Feb 3	Feb 18	Apr[d] 21	Apr 29	May[d] 6	May[d] 15	May 26	May 30	June 16
Tucannon River at Fish Hatchery	96	-	-	-	340	-	-	-	-	-	235	278	285	255	210	-	-
Tucannon River at Krouse Ranch	215	172	280	-	560[c]	640[c]	590	440	-	-	430	-	450[c]	330	-	265	1700±[c]
Pataha Creek at Pomeroy	77	40	77	86	168[e]	184[e]	58	44	81	-	-	56	-	38	40	150	31
Pataha Creek at Chard Road	146	49	176	218[e]	430[e]	535[e]	70	-	-	-	47	47	30	34	-	158	96
Tucannon River at Smith Hollow Road[f]	431	202	678	840	910	950	-	-	725	720	375	408	375	344	-	295	1510
Tucannon River at Powers Road	500	210	710	840	1080[c]	1050	-	735[c]	-	-[c]	-	415	-	340	-	275	1500±[c]

a/ Discharge, in cubic feet per second, from crest stage gages.

b/ The mid-January, 1980 storm was by far the most significant event of the wet season. It consisted of 4 peaks from January 12 through January 15.

c/ The bed at the Krouse and Powers Road gages probably underwent several substantial changes in configuration during these events.

d/ Between .25 and .50 inches of rain fell on these days at Pomeroy. Streamflow was primarily snowmelt with some added runoff.

e/ The relation between stream height (gage height) and discharge is poorly defined above 150 cfs for the stations on Pataha Creek. These discharges are based on extensions of the stage-discharge curve, using hydraulic geometry relations.

f/ Based on U.S.G.S. stage-discharge curve No. 22.

was only slightly below normal, the streamflow record (this chapter), the sediment budget (Chapter 4), and water quality data (Chapter 5) must be interpreted in light of their seasonal distributions.

CHAPTER 4

SEDIMENT TRANSPORT

Both suspended and bedload sediment were monitored at the six gages throughout the Tucannon basin during WY1980. Suspended sediment, primarily fine material, is carried throughout the main body of current, supported by the flow turbulence. Bedload sediment, supported by the bed, moves with a rolling or bouncing motion. Suspended sediment moves rapidly, essentially at the local velocity of the stream. It is flushed relatively efficiently in streams such as most of those in southeastern Washington, which are steep, turbulent, and transport a fine, silty suspended load. Bedload consists primarily of gravels and sands, and is transported at much slower rates. Bedload is usually sampled by capturing particles moving within three inches of the bed; suspended sediment is collected from the remainder of the flow depth. The combination of the two is known as total sediment load.

Sediment transported in the Tucannon River, Pataha Creek, and most streams in southeastern Washington is composed largely of silts (and clays) or gravels (and cobbles). The silts and clays are transported entirely in suspension. The gravels and other coarse materials are transported as bedload. Fine and medium sands, so abundant in most streams, may be moved in suspension or along the bed, depending on flow conditions and the local channel configuration. Material of these sizes is in very limited supply in the Tucannon River, and probably represents significantly less than five percent of the long-term sediment yield.

Suspended sediment constitutes the bulk of the total sediment load in most streams. In most geomorphic settings, bedload has been found to compose 5 to 40 percent of the total load. Our studies indicate that this percentage is normally much smaller in the Tucannon watershed and much of the four-county area of study, lending support to earlier estimates of one to five percent (Mapes, 1969; Boucher, 1970). Bedload transport remains an important, possibly critical, factor affecting habitat and channel stability.

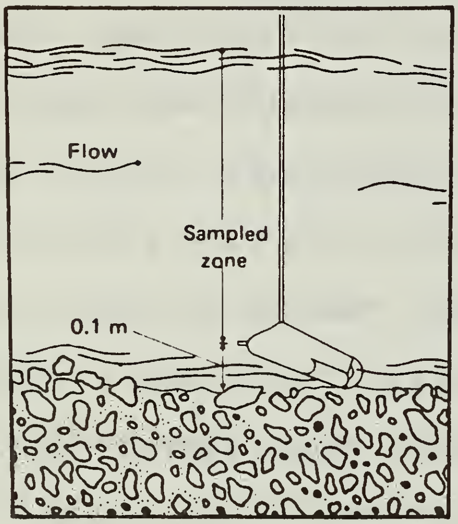
Sampling methods, observed transport rates during WY1980, and a discussion of these findings are presented in this chapter.

Sampling and Computational Procedures.

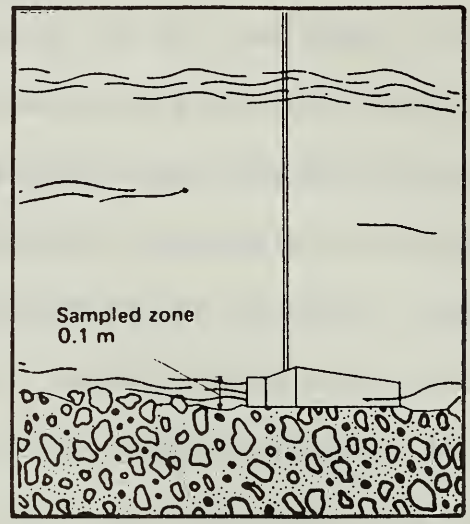
Suspended Sediment. Suspended sediment loads are computed as the product of average sediment concentration and streamflow. Both quantities must be known within reasonable tolerances.

All suspended sediment samples in this study were collected using standard samplers, known informally as "fish" (Figure 4.1). The sampler is designed so that the entrance velocity to a nozzle protruding from the nose is identical to that in the stream. In this study, two similar samplers of this design, but differing in size, were used. At low flows, a hand-held, 4-pound aluminum sampler (U.S. DH-48) was used; higher flows required the use of a 65-pound sampler (U.S. D-74) suspended from a cable and operated from a bridge.

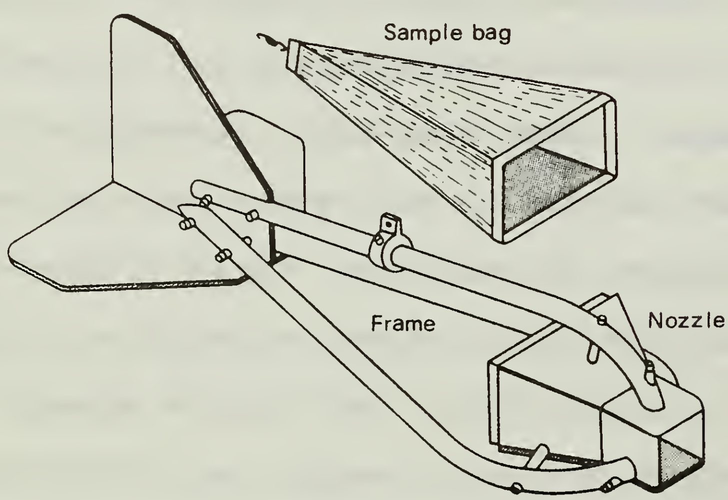
Most measurements were made by collection of sub-samples at 5 to 15 verticals across the channel. At very high flows, only 3 sub-samples were obtained at some stations. Verticals were situated so that each sampled an equal percentage of the streamflow.



Suspended Sediment Sampler



Bedload Sediment Sampler
(low to moderate flows)



Detail of High-Flow Bedload Sampler

Tucannon River Water Quality and Stream Habitat Study

Prepared for: USDA Soil Conservation Service

Figure 4.1. Sediment Sampling Equipment Used in the Tucannon Watershed, 1979-1980.

A depth-integrated sample was collected by the equal transit rate method. Collectively, these are considered to be representative of the average sediment concentration. Discharge at the time of sample collection was established from a reading of the staff gage or by direct measurement.

Previous studies in the Walla Walla and Palouse watersheds (Mapes, 1969; Boucher, 1970; McCool and Papendick, 1975) established that most of the suspended sediment transport occurs during brief periods of high flow. Similarly, negligible proportions of the yield of suspended sediment occurs at flows less than the mean discharge for the year; in most streams in eastern Washington, less than 10 percent of the yield occurs at discharges less than <u>twice</u> the yearly mean.

Data previously collected from the Tucannon River at Smith Hollow Road also indicated a substantial seasonal variation in suspended sediment concentrations. We therefore attempted to emphasize the highest flow periods and to distinguish the seasonal concentration patterns. Monitoring stations were chosen in part to enable collection of one or more samples per day at high flow. Additionally, single-stage samplers were installed at all stations to collect samples of brief runoff pulses (Figure 3.1).

Curves relating the samples sediment load (in tons per day) were prepared for each of the six stations. For illustration, suspended sediment rating curves at two representative stations are shown in Figures 4.2 and 4.3. Because extremely low and high flow suspended sediment concentrations are lacking, curves were extended

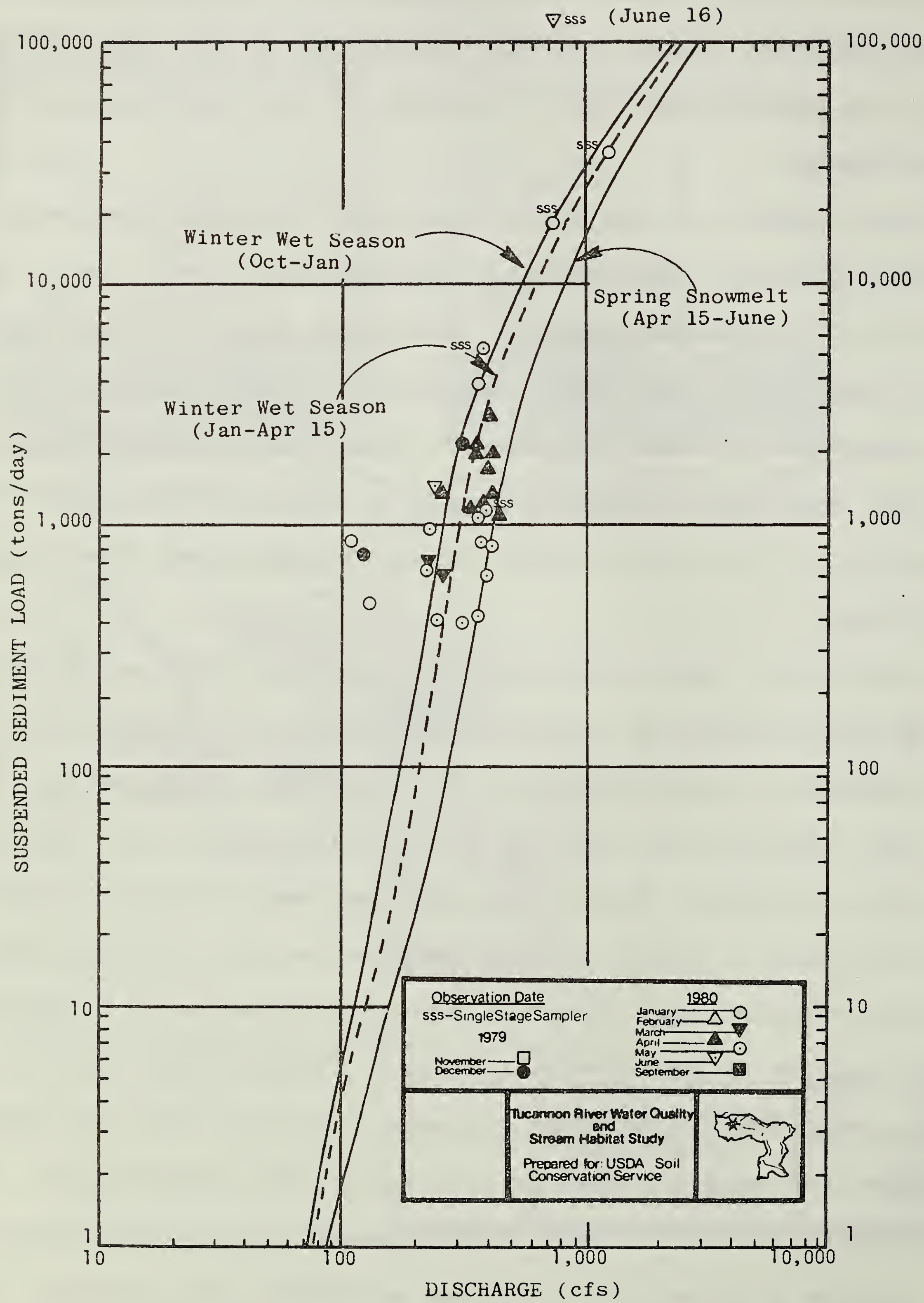


Figure 4.2. Suspended Sediment Rating Curve for Tucannon River at Smith Hollow Road (U.S.G.S. gaging station).

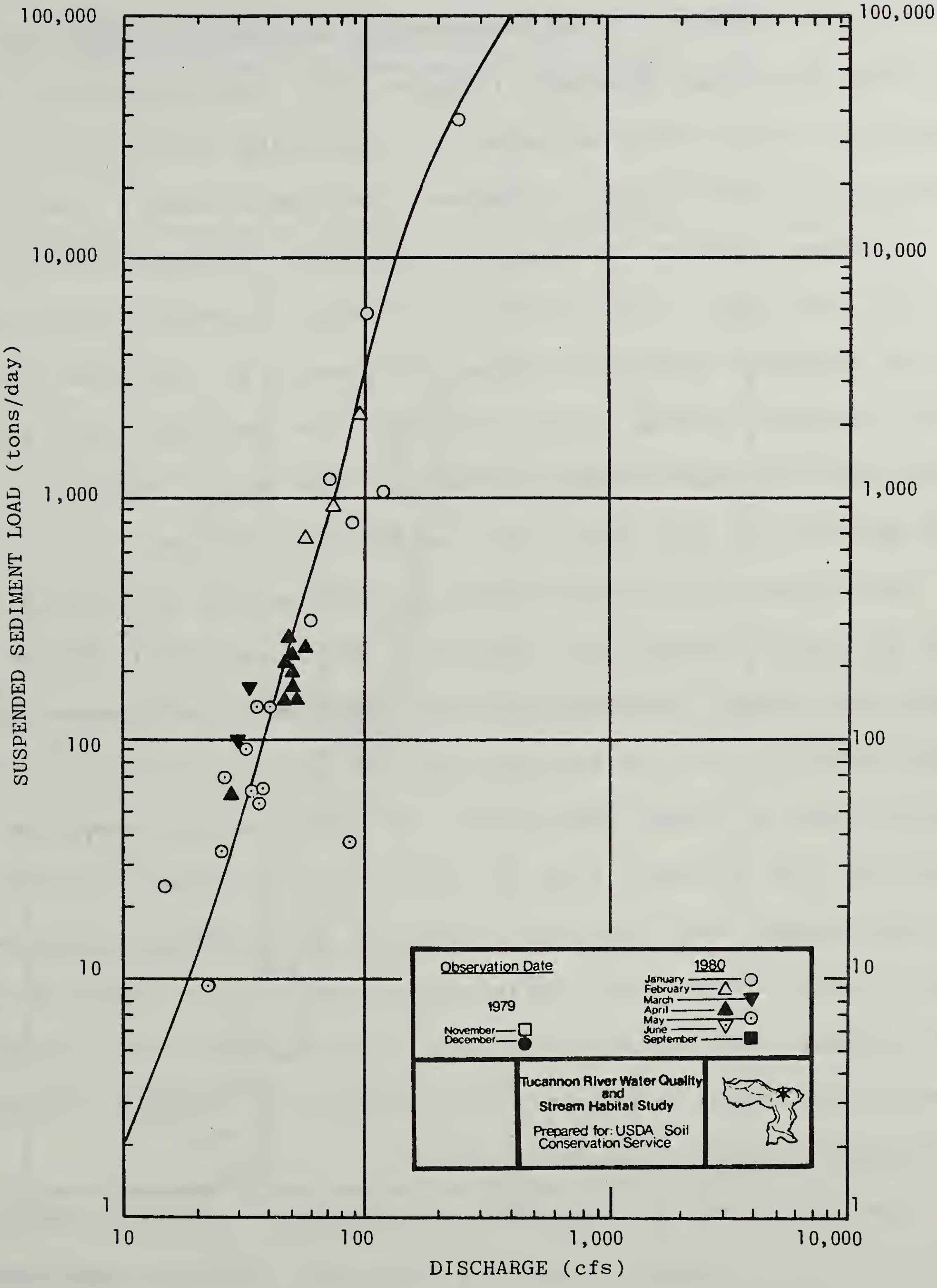


Figure 4.3. Suspended Sediment Rating Curve for Pataha Creek at Pomeroy

by comparison with other previously monitored gages in the area. For the stations on the main branch of the Tucannon River the curves were compared to the suspended sediment rating curve for the USGS gage near Starbuck (Figure 4.4). For stations on Pataha Creek the curves were compared to the rating curve for the now-discontinued USGS gage on Deadman Creek near Central Ferry.

Seasonal shifts in suspended sediment rating curves occurred at most stations. For a given discharge, snowmelt period suspended sediment transport rates are generally less than transport rates measured during winter storms. The seasonal shifts during water year 1980 are probably smaller than usual, due to the anomalous amounts of rain that fell during this period.

Data from the single-stage samplers appear generally consistent with the depth-integrated samples at both the Smith Hollow and Chard Road gages. Results are not acceptable at Pomeroy and the Krouse Ranch sites; we believe this is due to the placement of the sampler bank at these locations. No single-stage samplers were filled at the Hatchery site during the storm runoff period, and only one sample was obtained filled at Powers Road. The qualitative use of results from the single-stage samplers in defining the high-flow sediment rating curve appears to be possible at stations where there is empirical agreement with results of samples collected by the standard depth-integrated method.

The procedure of relating instantaneous sediment transport rates to the discharge record is the most commonly used means worldwide of computing sediment yields. The accuracy of the

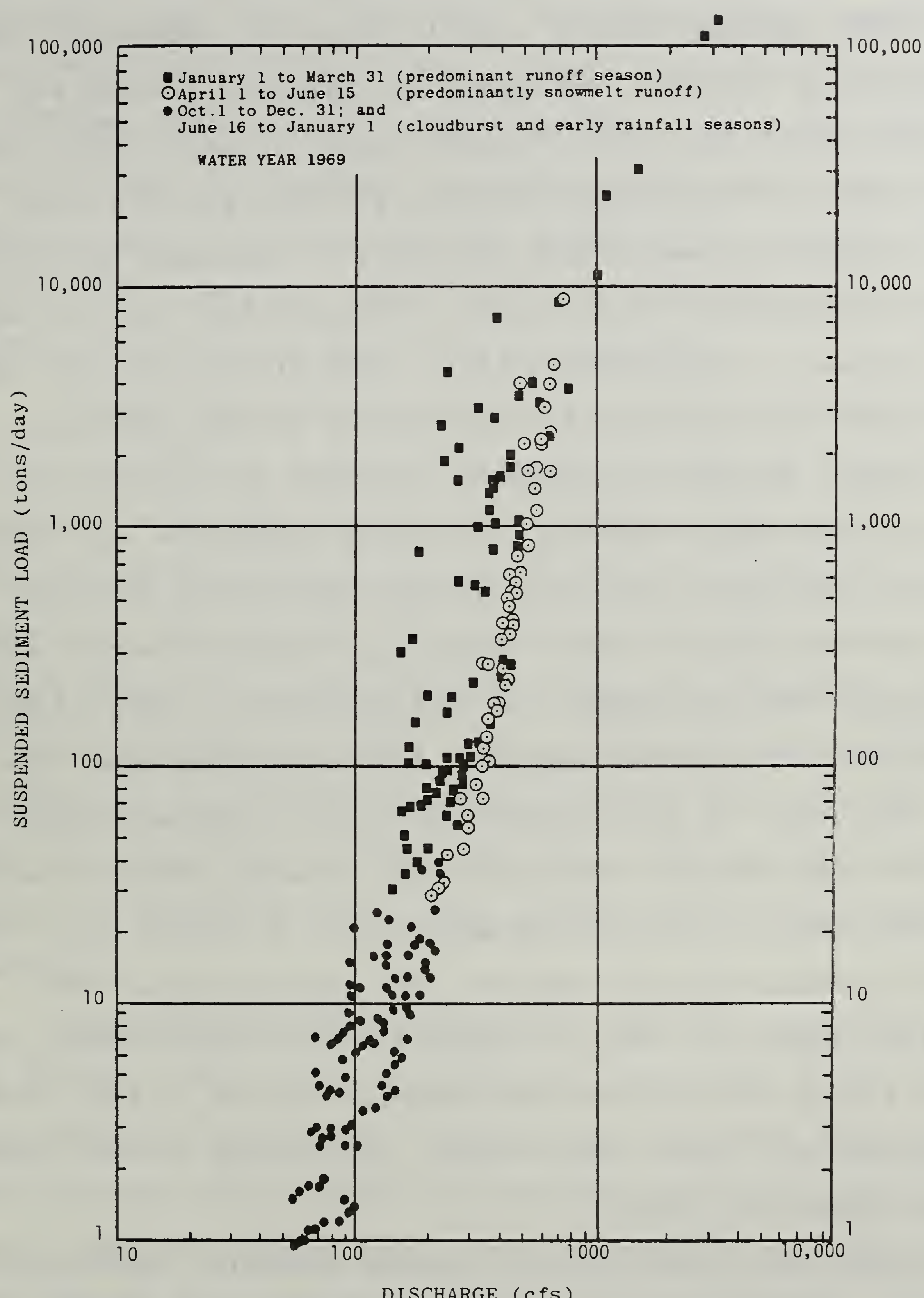


Figure 4.4. Suspended Sediment Rating Curve: Tucannon River Near Starbuck, Water Year 1969.

procedure depends on that of the discharge record, the number and dispersion of sampling results, and the degree of refinement used in analyzing the results. The number of samples collected was necessarily limited due to the unusual degree to which storm runoff during WY1980 was concentrated during a four-day period in mid-January. High-flow samples were collected at all gages and sufficient data were developed for each station, although these did not show the same degree of seasonal variation. Adequate to excellent discharge records are available at each station for the periods of highest flows. Analysis of sediment transport during the major storm period and every other day of varying streamflow was refined by computing the daily load on an hour-by-hour basis; half-hour subdivisions were used for brief storms or cloudburst runoff events.

Bedload. Bedload samples are collected with a modified Helley-Smith pressure-differential sampler. This device has come into general use during the past 5 years due to its high performance relative to experimentally-measured loads in sand-and-gravel streams. The bedload sampler is shown diagrammatically in Figure 4.1. As with the suspended sediment samplers, two similar models were used in this study, one made of aluminum for use while wading and the other a weighted 80-pound steel sampler for use in high flows when suspended on a cable from bridges. The mouths of both samplers are three inches on a side.

Although widely used in gravel-bedded channels, there is no direct evidence to establish the sampler's efficiency of measuremeant relative to "true" loads in pebble-bedded streams such as the Tucannon River. Where the bed is composed of cobbles and

and boulders, such as at the Hatchery station, the sampler tends to rest on the top of the rocks, and may not fully sample material in transit between the cobbles. Also, the size of the aperture (76x76 mm) limits entry to small cobbles. The 3-inch Helley-Smith probably may be reasonably assumed to under-sample the larger gravels and all cobbles, but the extent of this bias has not yet been determined. Pertinent experiments are now being conducted by the Federal Inter-Agency Sedimentation Committee.

Because bedload movement is not uniform across the channel, it is desirable to sample at as many positions as possible. Twenty positions were used for most measurements on the larger streams at low and moderate flows; ten positions, or occasionally five, were sampled at high stages. Ten positions were used at most times on Pataha Creek, in accordance with recommended procedures for a stream of this size (Emmett, 1980). During moderate and high flows, the sampler was raised after each sub-sampling to verify that the mouth was not clogged and to check the load. The bags were emptied when they were partially full, often several times in one cross-channel sampling.

Instantaneous bedload transport rates were measured and computed as follows. The active bed width was determined in the field by the observer. Backwaters, debris jams, and areas above water were omitted from the bed width in measuring the active portion. The active bed was divided into 10 or 20 equal widths, each of which was sampled for a period of usually 30 or 60 seconds. The unit bedload transport rate (per foot width of channel) was computed as

the combined oven-dried sample weight divided by the total time of sampling and the sampler width (0.25 feet). The whole-channel bedload transport rate was computed by multiplying the unit rate by the active bed width. The instantaneous bedload transport rate was related to the discharge at the time of sampling to develop an instantaneous bedload rating curve, similar to the suspended load rating curve. Figure 4.5 is the instantaneous bedload tranport rating curve for the Tucannon River at Smith Hollow. The relation between transport rate and discharge is also given for Pataha Creek at Pomeroy in Figure 4.6.

No bedload monitoring had previously been attempted in the streams of southeastern Washington, Thus, bedload rating curves are based entirely on measurements made by HEA staff during water year 1980. Bedload transport rates varied systematically with discharge; however, the extension of the curves to high and low flows is estimated. At the Krouse Ranch, bedload transport rates were much lower than predicted from the bedload rating curve during mid-May. We believe this condition is due to development of an armored bed at this station.

Computation Procedures. The general approach used in computing sediment discharge is that used by the U.S. Geological Survey (Porterfield, 1972). Detailed procedures, conventions, and means of relating sediment transport to streamflow are exactly those used by Emmett and Seitz (1974) in their studies near Lewiston. The one exception is that finer daily subdivisions were

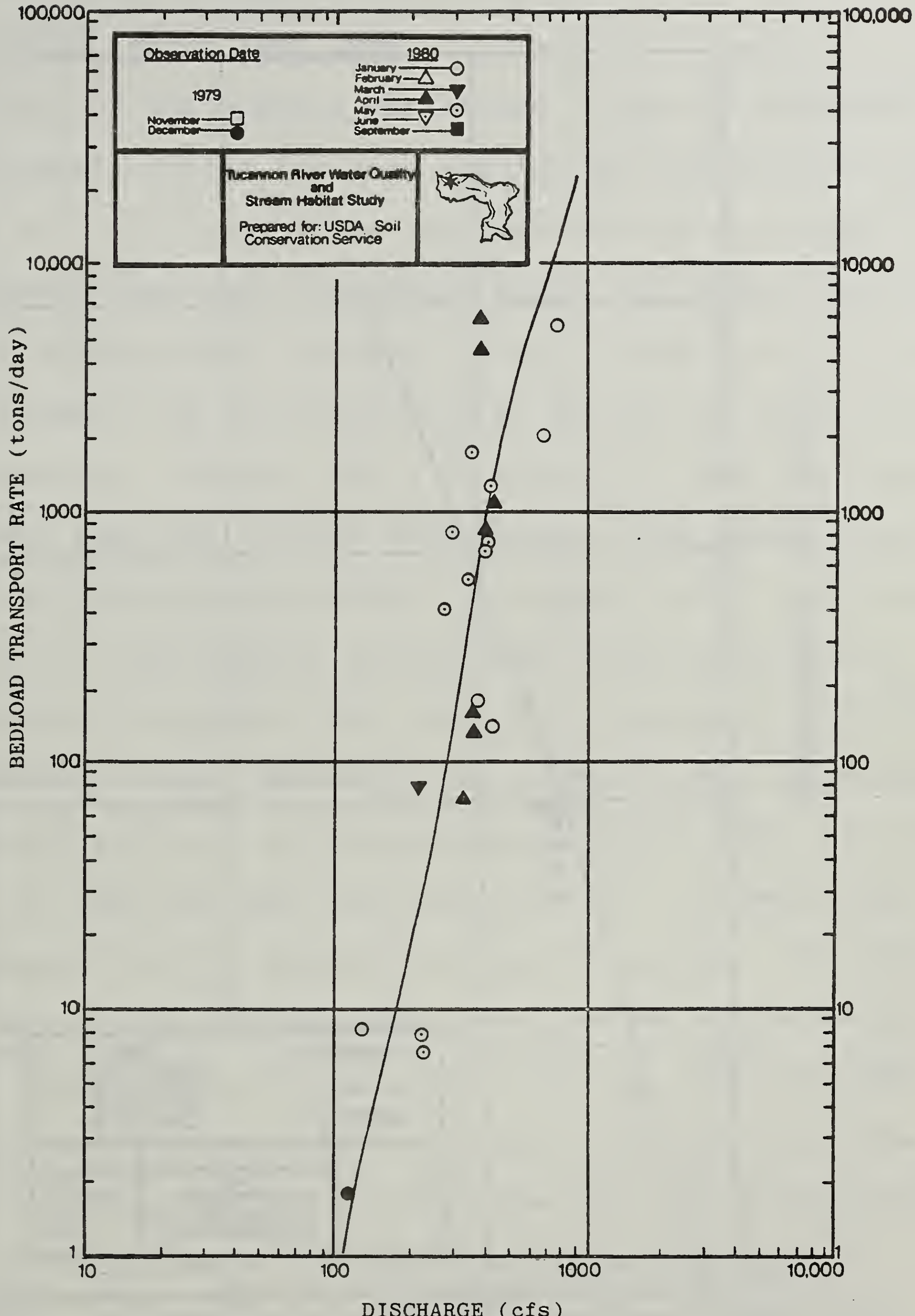


Figure 4.5. Instantaneous Bedload Transport Rating Curve, Tucannon River at Smith Hollow Road, (USGS gage).

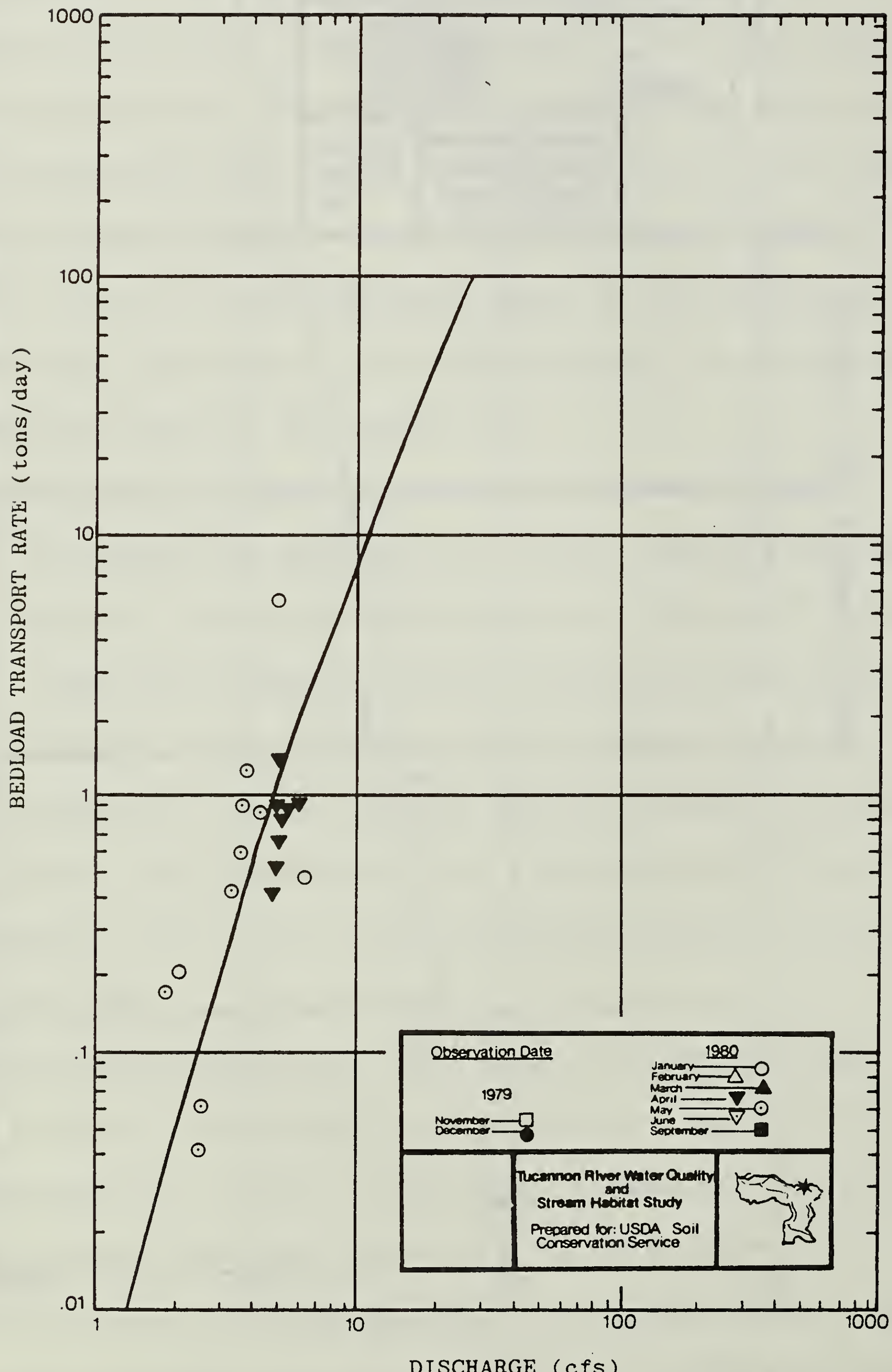


Figure 4.6. Instantaneous Bedload Transport Rating Curve, Tucannon River at Pataha Cr. at Pomeroy

applied to the Tucannon data due to the steeper relation of suspended-sediment transport with streamflow.

Sediment Yields, Water Year 1980

Estimates of the monthly variations in the suspended-and bedload-sediment yields for each station are presented in Table 4.1 and Figure 4.7. At five of the stations most of the annual suspended sediment load was transported during the 4 or 5 days of the mid-January storm period. Between 50 and 75 percent of the suspended sediment movement for the year occurred during the month of January at these stations. Roughly 40 to 65 percent of bedload transport during WY1980 also fell within this period. The lower proportion of bedload yields concentrated during the storm period is probably a reflection of bed mobility during other high-water events. No previous bedload transport data exist for comparison with WY1980.

A disproportionate amount of the sediment load originates in the lowland portions of the watershed. The lowest unit yields, 0.14 and 0.27 tons per acre were observed at the Pomeroy and Hatchery gages, the two stations furthest upstream. The largest observed unit yields was from the lower portion of the Pataha watershed, where the watershed between Pomeroy and Chard Road generated about 1.4 tons per acre, primarily during the January storms. Monitoring results indicate low unit yields were generated from the portions of the watershed below the mouth of Pataha Creek. In part, this accurately reflects conditions during WY1980, when the rain-on-snow event of January and the cloudbursts of May and June affected the middle elevations more

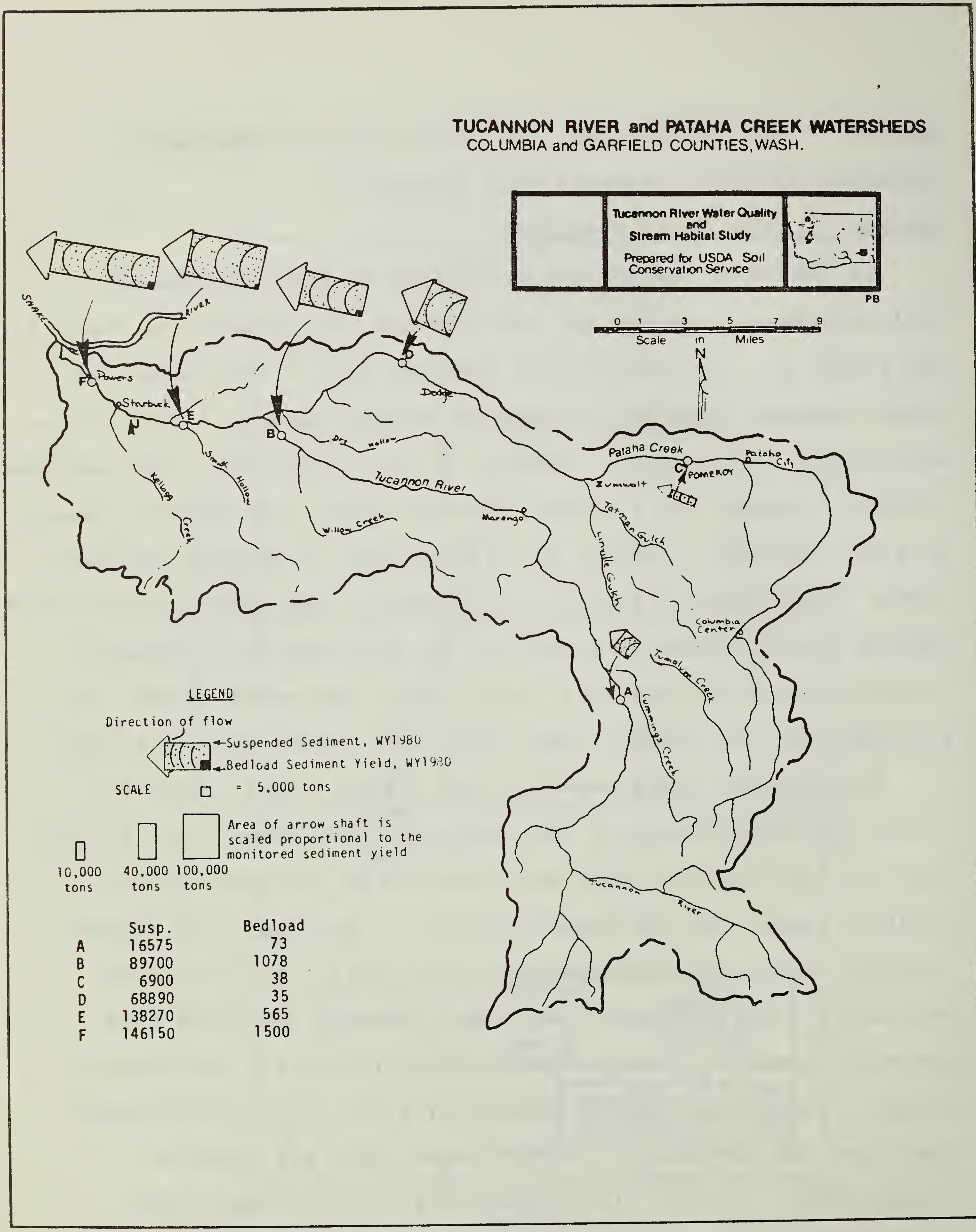


Figure 4.7. Summary Sediment Budget, Tucannon River Basin, WY1980.

Table 4.1 Monthly Variations in Suspended and Bedload Sediment Transport
Tucannon River Watershed, WY1980

Station Location	Drainage Area[a]	Type of Load[b]	Monthly Sediment Load (tons) (cfs)												Annual Total[c/]
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
Tucannon River at Fish Hatchery	96	susp	14.6	23.4	125.	7072.	612.8	413.	2292.	5514.	301.	91.2	64.1	52.7	16575.6
		bed	<0.01	<0.01	0.63	28.20	2.35	4.68	9.49	22.5	4.59	0.66	<0.01	<0.01	73.1
Tucannon River at Krouse Ranch	218	susp	54.8	69.9	160.6	58791.	1745.	1540.	7586.	8800.	10827.[d/][e/]	66.4	38.7	42.6	89722.2
		bed	0.40	0.76	2.08	669.0	21.1	18.6	150.	129.	86.5	0.70	0.18	0.27	1078.5
Pataha Creek at Pomeroy	77	susp	4.20	3.93	212.	2968.	910.	801.	993.	786.	125.	84.7	26.4	0.80	6915.0
		bed	<0.01	<0.01	0.71	22.5	4.33	3.41	4.47	2.40	0.37	0.08	<0.01	<0.01	38.2
Pataha Creek at Chard Road	146	susp	30.8	37.2	329.	52706.	8810.	2250.	2940.	1325.	234.	158.	50.0	17.2	68887.2
		bed	<0.01	<0.01	0.26	20.7	5.22	2.76	4.01	1.54	0.07	<0.01	<0.01	<0.01	34.6
Tucannon River at Smith Hollow Road	431	susp	161.	179.	746.	68595.	18251.	26080.	11628.	7849.3	4676.[d/]	42.1	32.2	31.6	138270.9
		bed	0.06	0.09	0.94	280.6	28.7	15.1	80.8	79.7	8.78	0.15	<0.01	0.02	564.9
Tucannon River at Powers Road	500	susp	159.	231.	892.	72257.	10564.	14505.	18916.	20711.	7749.[d/]	81.2	38.1	37.9	146141.2
		bed	5.30	7.46	21.4	729.54	99.0	122.7	201.2	208.7	107.0	6.58	2.95	3.32	1515.1

[a] Drainage basin areas in square miles.

[b] susp: suspended; bed: bedload.

[c] Total computed by summation. Actual precision no more than 2 to 3 significant figures.

[d] Cloudburst of June 16, 1980 appreciably affected these stations.

[e] Sediment loads for June at this gage based on inferred hydrograph and sediment rating curves for June 16 cloudburst, and should be considered as a best estimate only. Exclusive of this event, suspended sediment load for the month was 427 tons, and bed-oad was 15.7 tons.

than the lower portions of the watershed. This finding may also reflect an over-estimate of actual loads transported through the Krouse Ranch gage. The bed at this gage is so mobile during high flows that we were unable to sustain valid stage-discharge relations during the January and June runoff events. As sediment transport rates in the Tucannon watershed increase rapidly with streamflow, any over-estimate of the magnitude or duration of the high flows at this site would be reflected in a greater over-estimate of sediment yields.

Discussion.

Suspended sediment loads at a given discharge were broadly similar in WY1980 to those observed in the course of WY1969 sampling conducted by the U. S. Geological Survey during equivalent seasons (figure 4.2, 4.4). Some samples collected during the first storm of the year and the anomalous January runoff events contained relatively greater concentrations than those observed during WY1969, which serves as the basis for figure 4.4. These observations, however, fall well within the scatter for early-winter events in other years. Year-to-year and basin-to-basin variabilities in sediment yields are shown in Table 4.2. In relation solely to peak and mean discharges, sediment yields monitored in the course of this study are larger than might be expected based on observed loads in WY1967 or WY1968, and lower than would be indicated by the results from WY1964, WY1966, or WY1970. Factors other than runoff, then, are essential influences on sediment yields in the Tucannon basin.

Table 4.2 Variability of Measured Suspended-Sediment Yield, Tucannon Watershed, By Year, With Streamflow, and In Comparison to Nearby Drainages a/

	Tucannon River near Starbuck b/ Drainage Area = 431 sq. mi.				Walla Walla R. nr. Touchet b/ DA=1657 sq.mi.	Meadow Creek nr Central Ferry DA=66 sq.mi.	Deadman Creek nr. Central Ferry b/ DA=135 sq. mi.
Water Year c/	Instantaneous Peak Discharge	Highest Mean Daily Discharge	Mean Annual Discharge	Suspended-Sediment Yield	Suspended-Sediment Yield	Suspended-Sediment Yield (tons/year)	Suspended-Sediment Yield (tons/year)
	(cfs)	(cfs)	(cfs)	(tons/year)	(tons/year)	(tons/year)	(tons/year)
1963	4700	2200	134	399,275 d/	1,380,000	-	-
1964	1880	400	143	148,093	248,000	-	-
1965	7980	4620	277	3,145,693	10,100,000	-	-
1966	2170	330	124	155,769	-	80,000	46,000
1967	512	485	135	17,289	-	2,200	2,700
1968	515	505	133	9,238	-	860	2,200
1969	3990	2930	231	526,664	-	32,000	59,000
1970	1030	866	163	219,324	-	44,000	130,000
1980	1510	710	158	138,271	-	-	-

a/ Sources of data: Mapes (1969) and annual water-resource data reports of the U.S. Geological Survey.
b/ See Table 2.1 and Appendix A for periods of record and concurrent data collected.
c/ Water year begins Oct. 1 and ends the following Sept. 30. Data for Walla Walla River, collected on a July 1 to June 30 basis, are assigned to water year beginning Oct. 1.
d/ Data throughout table are presented as previously published. Actual precision limited to 2 or 3 significant figures See discussion of notation and conventions in Chapter 1.

Review of the older suspended-sediment data collected by the U.S. Geological Survey indicates that sediment transport rates vary strongly with ground conditions and also with season. The depth and distribution of frozen ground, the amount and condition of snow on the ground, and antecedent soil moisture are all considered ground conditions. Substantial year-to-year differences in sediment transport rates at any given discharge may occur, (Table 4.2) depending on the condition of the ground during the significant sediment-producing events. Indicative of these differences is figure 4.8, which suggests that suspended-sediment concentrations at a given streamflow in Deadman Creek were commonly 3 to 8 times higher for much of WY1970 than during WY1969. The Deadman Creek watershed adjoins the Pataha Creek basin near Pomeroy; although slightly drier and lower, the Deadman Creek drainage is broadly similar to the lower Pataha and Tucannon watersheds.

Seasonal variations in suspended-sediment concentrations are also substantial. Broadly three seasons may be recognized--winter storm runoff, peak snowmelt, and summer cloudburst. Runoff from the first one or two storms of the winter season often transports significantly larger concentrations of sediment than do later events. During the present study, this appears to have held true for the storm of December 5, 1979; for lack of a sufficient number of samples, this storm was not differentiated from other winter events. Subsequent studies should explore this intra-seasonal variation. Among the consequences to habitat management is the possibility that sediment may affect fall-spawning runs to a greater degree. Additionally, water quality para-

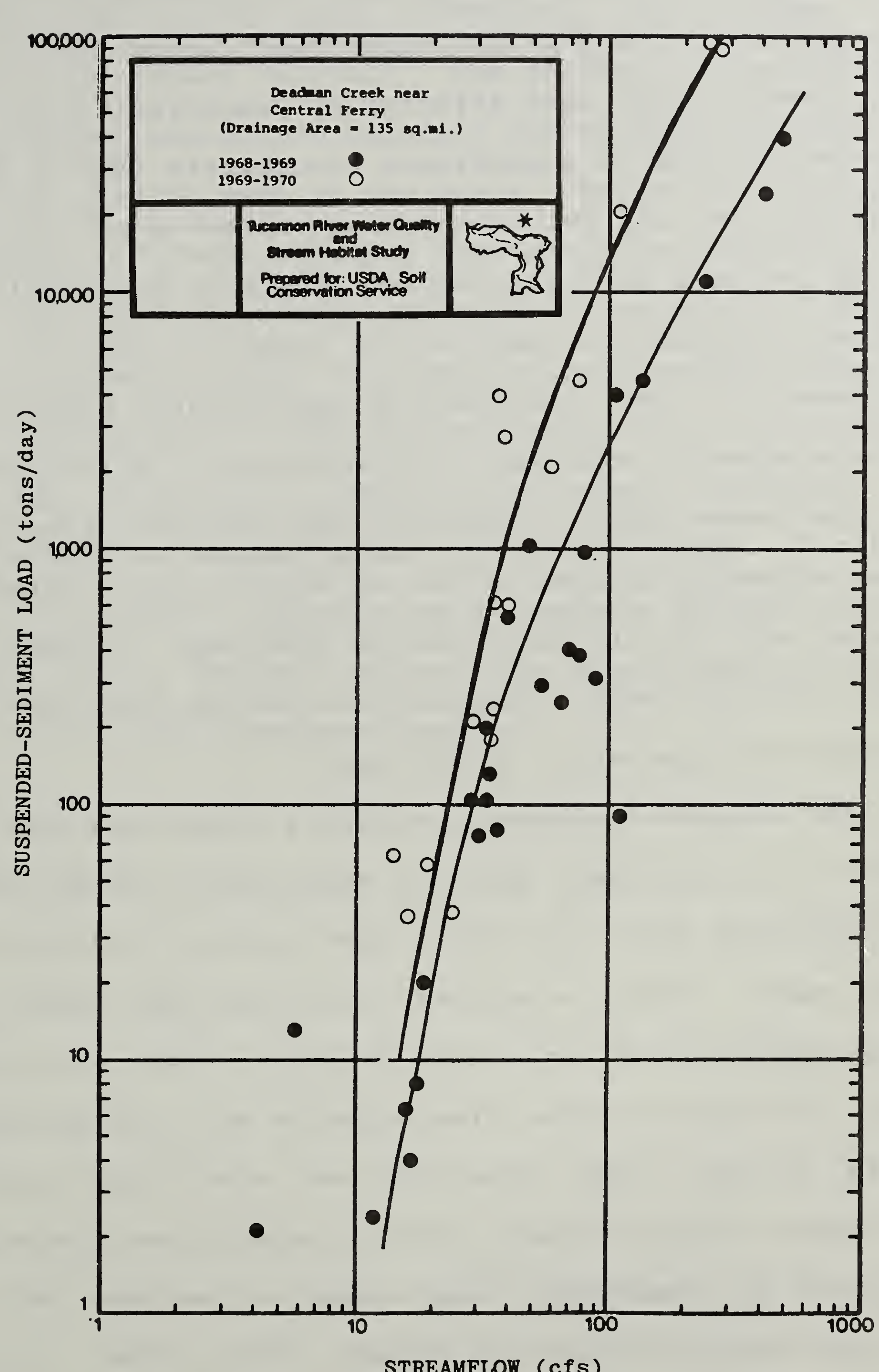


Figure 4.8. Annual Variability In Suspended-Sediment Load At a Given Discharge. Deadman Creek drains the watershed immediately north of the Pataha Creek basin; it has watershed properties broad similar to those of the lower Tucannon and Pataha drainages. Developed from basic data collected by the U.S. Geological Survey.

meters associated with sediment or related to runoff from cultivated or disturbed areas may show similar early-winter maxima. Sediment concentrations are much lower during the seasonal snow-melt crest, except when affected by concurrent rainfall. Concentrations on days of significant cloudbursts (May 9, May 30, June 1), approached but did not exceed those observed at the same flows during the main period of winter runoff at all stations. Extraordinary cloudbursts, such as the events of June 16, 1980 or September 19, 1966, can generate much greater concentrations. Mudflow deposits observed in tributaries to Willow Creek following the more recent major cloudburst were probably associated with flows exceeding concentrations of 500,000 mg/l. Single-stage sampler data for the Smith Hollow Road gage, if these are truly valid, indicate peak concentrations during this event at that station were upwards of 60,000 mg/l.

The suspended sediment transport rates monitored during WY1980 at the Hatchery Gage are reportedly several times higher than expected from U.S. Forest Service data collected during other years. They are several times less than those observed in the Pataha Creek forks near Columbia Center (C. Benoit, unpubl. data). We believe these discrepancies are attributable to several factors, some reflecting real conditions in the watershed and others being artifacts of the computational procedure. First, there was an anomalously large amount of sediment delivered to the Tucannon channel during the January 1980 storms. In the Blue Mountain portions of the basin, these storms were unusual both in their warmth and in being intense rain-on-snow events. The major

mud avalanche in the Bear Creek sub-basin is one indication of the effect of these storms at the upper elevations, which seldom receive substantial January rainfall. Few previous observations of concentrations during mid-winter rainfall runoff have been made within the Blue Mountains part of the basin. Major mud avalanches can, in themselves, increase sediment concentrations many times above normal during the first few storms after their occurrence. Additionally, while snowmelt runoff for the year was somewhat below normal in the upper basin, it was concentrated during a two-week peak in early May, resulting in greater than normal transport capacity and perhaps an unusual amount of bank collapse. Finally, use of hourly or bi-hourly subdivisions to compute sediment yields tends to produce values somewhat higher than Forest Service procedures based on the daily discharge means.

CHAPTER 5

WATER QUALITY

In addition to sediment, streams transport dissolved minerals and other materials that affect the suitability of the water for habitat and other beneficial uses. Customarily, several constituents of principal concern are selected for monitoring. The choice of these constituents is usually made by professionals previously familiar with the area, and may be governed in part by regulatory standards or water quality goals for the specific watershed.

The Soil Conservation Service staff selected specific conductance, dissolved nitrate, and turbidity as constituents of concern to be monitored in the Tucannon River basin study. These constituents were monitored during WY1980 by the HEA staff at the six gaging stations. Emphasis was placed on the winter storm and peak snowmelt runoff periods, when the concentrations of all constituents are most variable. Supplemental observations were made at scattered locations elsewhere in the basin in the course of the habitat investigations or when unusual conditions prevailed. The project staff also measured water temperatures while conducting other sampling. Initially, these measurements were collected to provide a context for the sediment and water quality measurements, since several constituents may vary somewhat with stream temperature. Once temperature was recognized as a habitat constraint, measurements were made more frequently.

Previously published data on water quality in the Tucannon watershed are limited. Water temperatures were measured at Marengo

during several periods in the 1920's and 1930's, and at the USGS gage near Starbuck (Smith Hollow Road) from 1962 through 1970. During WY1974, the Geological Survey staff also collected monthly water quality samples at this station. These were analyzed for a broad spectrum of physical and chemical characteristics. The Washington State Department of Ecology continues to monitor water-quality in the Tucannon River at Powers on a quarterly basis. This abbreviated program, begun in 1977, presently includes quarterly analyses for specific conductance, fecal coliform, and nitrogen and phosphorus species. The State Department of Game and Fish has maintained a continuous record of water temperatures on the upper Tucannon River below Cummings Creek since the summer of 1978.

With the notable exception of temperature, the quality of water in the Tucannon River is generally suitable for aquatic habitat and most other beneficial uses. The percentage of snowmelt is high during most seasons of the year, serving to dilute salts, nutrients, and bacteria entering the stream via seepage into the stream and from rainfall runoff. Salinity and nutrient concentrations in Pataha Creek are higher than those in the Tucannon River, even upstream of the Pomeroy sewage treatment plant. Water temperatures are more variable and exhibit greater seasonal extremes in Pataha Creek.

A comprehensive listing of water quality measurements made during this study is presented by date in Appendix F. These data are summarized in Table 5.1, expressed as ranges for each station by runoff season. The seasonal and geographical variations in each constituent are discussed in the following paragraphs.

Table 5.1. Downstream and Seasonal Ranges in Selected Water Quality Parameters

Tucannon River Basin, 1979-1980

Designation[a/]	Name	Drainage Area (sq. mi.)	Water Temp. (°C) No.	min	med	max	NO_3+NO_2 (mg/l-N) No.	min	med	max	Turbidity (NTU) No.	min	med	max	Specific Conductance (μmhos/am) No.	min	med	max
A	Tucannon R. at Hatchery	90																
	Nov. 1 - Apr. 15[b/]		18	2.5	5.5	11.0	4	0.055	-	0.125	5	1.65	4.2	12.8	6	44	45	72
	Apr. 15 - May 25[c/]		13	5.8	8.0	11.8	6	0.025	0.075	0.155	6	2.4	3.7	5.4	7	32	37	42
	May 25 - Sept. 30[d/]		1		14		1		0.065		1		1.4		1		79	
G	Tucannon R. at Marengo	156																
	Nov. 1 - Apr. 15						2	0.025	-	0.450	2	2.6	-	6.4	3	58	62	79
	Apr. 15 - May 25						2	0.075	0.075	0.075	2	4.8	-	5.4	0			
	May 25 - Sept. 30						1		0.075				1.4		1		91	
B	Tucannon R. at Krouse Rch	215																
	Nov. 1 - Apr. 15		20	2.5	4.5	9.5	6	0.180	0.380	1.025	12	3.5	85.7	285	12	59	66	100
	Apr. 15 - May 25		13	10.2	12.0	17.0	5	0.065	0.150	0.325	6	6.6	8.4	10.5	9	50	55	62
	May 25 - Sept. 30						1		0.025		1		1.1		1		100	
C	Pataha Cr. at Pomeroy	77																
	Nov. 1 - Apr. 1		6	3.5	6.0	7.0	8	0.695	1.155	1.755	14	11	492	3400	6	75	95	142
	Apr. 1 - May 25		13	7.0	12.0	14.5	6	0.355	0.475	0.575	6	15.4	25.5	67	8	85	98	160
	May 25 - Sept. 30[e/]						1		0.865		1		2.1		1		230	
D	Pataha Cr. at Chard Rd.	146																
	Nov. 1 - Apr. 1		17	0.2	2.5	6.5	5	1.175	1.325	1.585	9	11.0	72.5	2400	6	63	96	201
	Apr. 1 - May 25		14	11.8	13.8	18.0	6	0.475	0.625	0.675	6	15.0	28.0	84.0	8	103	121	148
	May 25 - Sept. 30						1		0.705		1		2.3		1		239	
E	Tucannon R. at Smith Hollow	431																
	Nov. 1 - Apr. 15		17	4.0	5.5	7.0	6	0.275	0.520	1.175	10	4.3	49	2075	7	64	98	117
	Apr. 15 - May 25		13	11.5	13.0	17.0	6	0.075	0.175	0.365	6	8.4	12.6	88	8	65	71	78
	May 25 - Sept. 30																	
F	Tucannon R. at Powers Rd.	500																
	Nov. 1 - Apr. 15		15	2.9	5.9	12.5	6	0.315	0.450	1.175	11	4.5	80	4860	8	83	100	141
	Apr. 15 - May 25		12	12.0	14.5	18.0	5	0.025	0.275	0.355	5	6.0	29	70	7	70	75	172
	May 25 - Sept. 30						1		0.105		1		2.1		1		153	

a/ Designation on location map.

b/ Season during which storm runoff was probably the major water quality influence.

c/ Season during which peak snowmelt runoff was the predominant water quality influence; begins April 1 on Pataha Creek, April 15 on Tucannon.

d/ Summer season, with gradually-diminishing snowmelt runoff and numerous thunderstorms.

Specific Conductance.

Specific conductance, also known as conductivity, is a measure of the fluid's ability to conduct an electrical current. It is expressed as the reciprocal of the resistance (ohms). Pure water has a very low specific conductance, but as ionic concentrations increase, specific conductance also increases. Therefore, it is used as a general indication of dissolved mineral content. In most natural waters in the Northwest, including those throughout the Tucannon basin, the specific conductance is relatively low. It is measured in micromhos per centimeter at 25°C.

Specific conductance was measured during this study on unfiltered* depth-integrated samples collected with a USDH-48 sampler. The temperature of the stream was also measured at the time of collection. Specific conductance was measured using a YSI Model 33 conductivity meter, calibrated regularly. Measurements were made at the HEA field office during late-evening of the sampling day, after the samples had gradually warmed to 25°C.

Specific conductance at all stations on the Tucannon River varied seasonally. The lowest values generally occurred on one of the days of peak snowmelt, with the highest values occurring in late fall or during winter baseflow periods. In the downstream direction, there is a consistent and increasing progression in the median for both major runoff seasons. Values at Powers are generally double those at the Tucannon Hatchery; readings at the Krouse

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* As a major focus of this study is on aquatic habitat and the effect of sediment on intragravel water quality, specific conductance was measured on unfiltered samples. Results of measurements made in the course of this study may differ slightly from conductivity determinations made on filtered samples.

Ranch gage were usually 30 to 50 percent higher than those at the upper station. Marked seasonal changes in both nutrients and salts were observed in Pataha Creek. This may reflect land use, effluent discharge, or the influence of several warm springs flowing into the creek near and upstream of Pomeroy. The highest conductivity reading (305 μmhos/cm) during the year was made on a grab sample collected from Linville Gulch on Feb. 10, 1980 (Table F-7). Substantial additional data are needed to identify the sources of salts in the Pataha watershed.

Conductivity measurements were made on the single-stage samples collected at the Chard Road gage on Pataha Creek during the January storms. These samples, collected at flows of about 160 to 1120 cfs, had unfiltered specific conductances of 200 to 270 μmhos/cm (at 25° C). The readings were made 5 and 7 days after the bottles had filled -- the only measurements in this study not reported to be made within 12 hours of collection. The samples were frozen when removed from the gage. Other high-flow samples collected in the standard depth-integrated manner at this station had measured conductivities of 60-100 μmhos/cm. The differences may be in part due to a number of factors, including:

1. Possible interference of high suspended sediment concentrations on the measurement.
2. Specific conductances may actually be greater during the rising stages of a large regional storm.
3. Freezing and thawing may have affected the conductivities.
4. Solutes may have been released from the sediment collected with the samples.

This last process, if actually occurring, would be reflective of changes that might take place within the bed gravels following emplacement of fine sediment.

Nitrate and Nitrite.

The oxidized forms of inorganic nitrogen were chosen as the water quality parameter indicative of dissolved nutrients.

Nitrogen is usually present in soil or biologic matter; oxidation of this material produces nitrate and nitrite. A large amount of inorganic nitrogen is also applied to the Tucannon watershed as fertilizer, some of which enters the stream net either in dissolved or adsorbed form.

Natural waters generally contain much greater concentrations of nitrate (NO_3) than nitrite (NO_2). Nitrite often comprises a few percent of the combined total. Within the restricted environment of streambed gravels, it can prove toxic to incubating eggs at low concentrations.

Measurements of nitrate plus nitrite were usually made on unfiltered waters collected with a DH-48 Bausch and Lomb mini-spectrophotometer using commercially-prepared reagents, which reduce and diazotize the sample with N-1 naphthalene ethylene diamine. The procedure was calibrated once during the course of this study against two samples of known concentration (0.32 and 12.2 mg/l-N), resulting in agreement within six and two percent, respectively.

As in many other streams, levels of inorganic nitrogen vary seasonally and with discharge at each monitoring station in the Tucannon watershed. This conclusion is based both on the results

of previous sampling by the U.S. Geological Survey and the Washington State Department of Ecology and measurements made during the 1980 water year (Table 5.1). The data from most stations suggest that nitrate plus nitrite levels vary directly but weakly with discharge, and that for a given discharge, concentrations tend to be 2 to 10 times higher during the season of storm runoff compared with the peak snowmelt period.

Nitrogen levels were found to be much lower at the hatchery gage than at other stations in the watershed, with seasonal differences being less pronounced. Higher concentrations and greater seasonal contrasts were observed at the stations near the river mouth. The data indicate a systematic downstream increase in inorganic nitrogen concentrations at stations on the Tucannon River, during the winter, peak snowmelt, and late summer seasons.

A recent study by the State Department of Ecology staff concluded that the Pomeroy waste treatment plant, which discharges into Pataha Creek, accounts for a significant percentage of nutrient outflow from the watershed. The amount of inorganic nitrogen released from the plant during the summer months is equivalent to 60 to 70 percent of the outflow, measured during the same season in the Tucannon River at Powers Road (Chase, Egbert, and Robb, 1980). The State study assumes downstream conservation of inorganic nitrogen in developing these computations.

Turbidity.

Turbidity is a measure of the light-scattering and light-absorbing properties of a fluid. The turbidity, or cloudiness, of water is an indirect indication of the amount of suspended mineral and organic material in the sample. During the winter and peak

snowmelt periods in the Tucannon basin, when most measurements were made, virtually all of the turbidity was probably attributable to suspended silts and clays.

A simple physical property, turbidity is readily measured in the field using one of many types of turbidimeters. Turbidity is a widely-used water quality parameter largely because of its simplicity, reproducibility, and the fact that results may be obtained on the spot. Interpretation and evaluation of turbidity measurements are more problematic. Turbidity is considered as an index of two general stream processes. First, the turbidity of a sample may not correlate with the suspended sediment concentration. Many unsuccessful efforts have been made to establish such a correlation for the Palouse-type streams of southeastern Washington, (Phil Boucher, USGS, Pasco). Second, turbidity may be an index of the propensity of settleable solids to adversely affect habitat values. Use of turbidity measurements for such purposes is controversial, and is accepted by a small proportion of biological and hydrological professionals. There appear to be four ways in which turbidity might affect aquatic habitat in the Tucannon system:

1. Fine materials in suspension might limit sunlight penetration, and constrain primary productivity.
2. Turbidities above 30 to 50 mg/l may inhibit feeding success; there is disagreement among aquatic biologists regarding the extent and importance of this constraint.

3. Moderate and high turbidities, especially during the summer months, might substantially reduce angling activity and/or success.
4. Turbidity may be a cause or an indicator of many biologic management problems in the Snake River reservoirs; the sources and seasonal variation of turbidity may be of interest in managing the fishery resource beyond the boundaries of the Tucannon watershed.

Turbidity was monitored at the six gaging stations in the Tucannon basin during WY1980. All measurements were made using a Bausch and Lomb (Mini-spec 20) nephelometric turbidimeter, calibrated prior to each use with fresh commercially-prepared standards. Samples used for turbidity measurements were collected in pint (450 ml) bottles with a DH-48 suspended sediment sampler. A sub-sample of 5 ml was drawn from the pint bottle following vigorous shaking, and used for the turbidity measurement.

Observed turbidities throughout the Tucannon watershed are related to discharge, increasing exponentially with streamflow (Table 5.1). Turbidities also vary seasonally, as shown for three stations in Figure 5.1. The limited data for each station suggest that during the peak snowmelt season and during some times of receeding storm runoff, turbidities vary with discharge in a manner quite different than during the winter storm season. Finally, the discharge-turbidity relations for Pataha Creek, and for the Tucannon River above and below Pataha Creek are distinct. At a given discharge, turbidities in Pataha Creek may be about two orders of magnitude greater than in

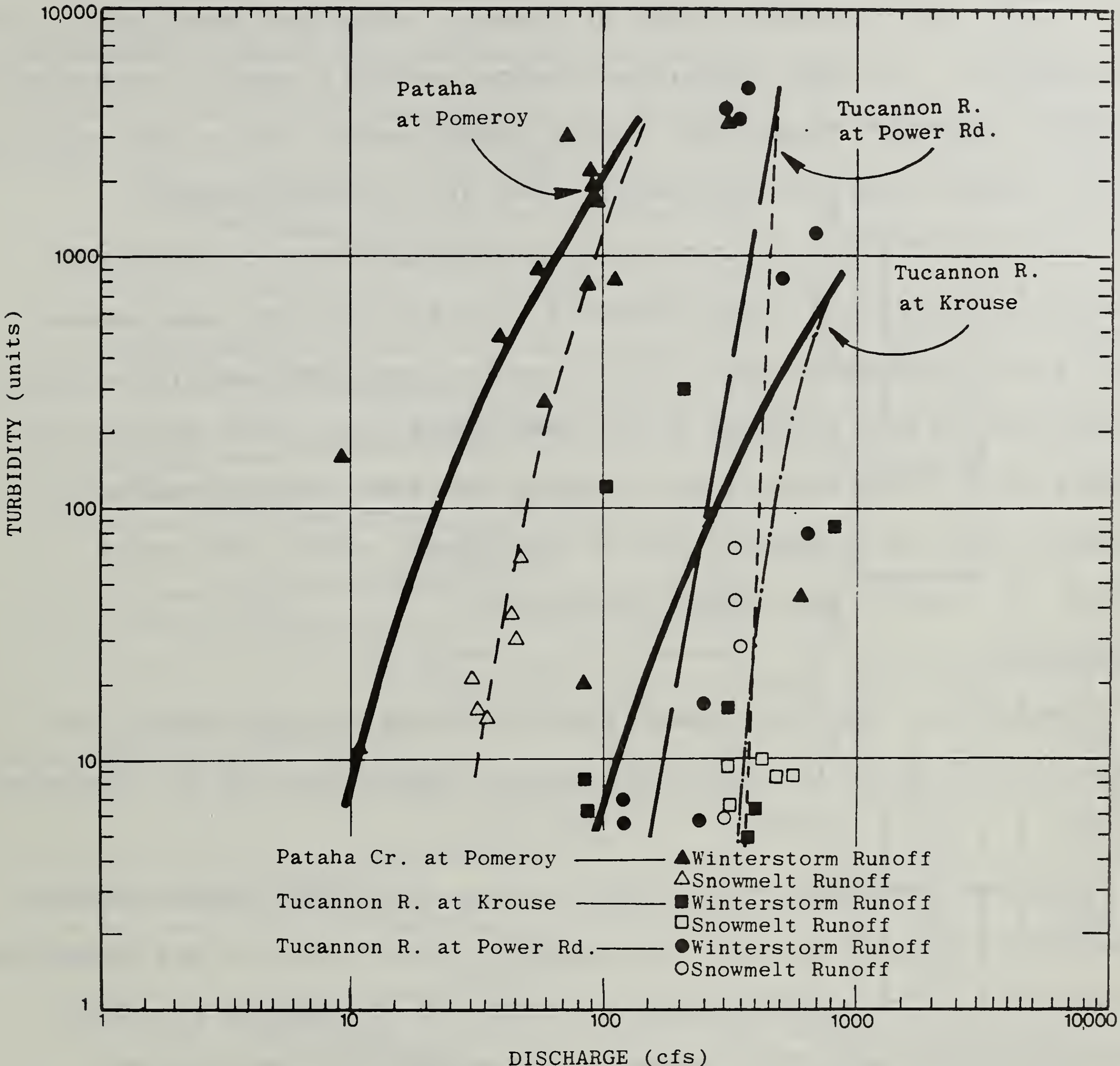

Figure 5.1. Relation of Turbidity to Instantaneous Discharge, Tucannon River Basin, Washington. These curves are schematic; because of the very wide range of observed values, data are insufficient to establish usable quantitative relations. See discussion in text.

the Tucannon River at the Krouse Ranch, above the Pataha confluence. The data for the Tucannon River at Powers, below the confluence, are intermediate. At high discharges during rainfall runoff, turbidities at Powers converge toward the Pataha Creek curves, while the relation for the snowmelt season approaches that at the Krouse Ranch.

Fishing activity is apparently discouraged when turbidities exceed a threshold of 30 to 50 NTU's. At the Hatchery and Krouse Ranch gages--representative of the reaches used for angling--ambient turbidities in the Tucannon River were below this level during all snowmelt and summer samplings. During the 1980 fishing season, turbidity did not constrain use of the river, except for brief periods of runoff from summer cloudbursts.

Temperature.

Temperature has been identified by biologists Don Kelley and Stacy Li as a major influence on aquatic populations in the Tucannon River.

Observed temperatures in the Tucannon River and Pataha Creeks during the winter storm and the snowmelt runoff periods are summarized in Table 5.1. The measurements were made in the course of other sampling activities. This summary is intended for descriptive purposes only. A quantitative expression of the temperature regime in the two streams is presented separately by Kelley and Li.

The importance of a riparian canopy in defining stream temperatures has been identified in many studies. Both maximum and mean monthly temperatures in the river may have increased following the floods of the 1964-65 winter season (Figure 5.2), which resulted

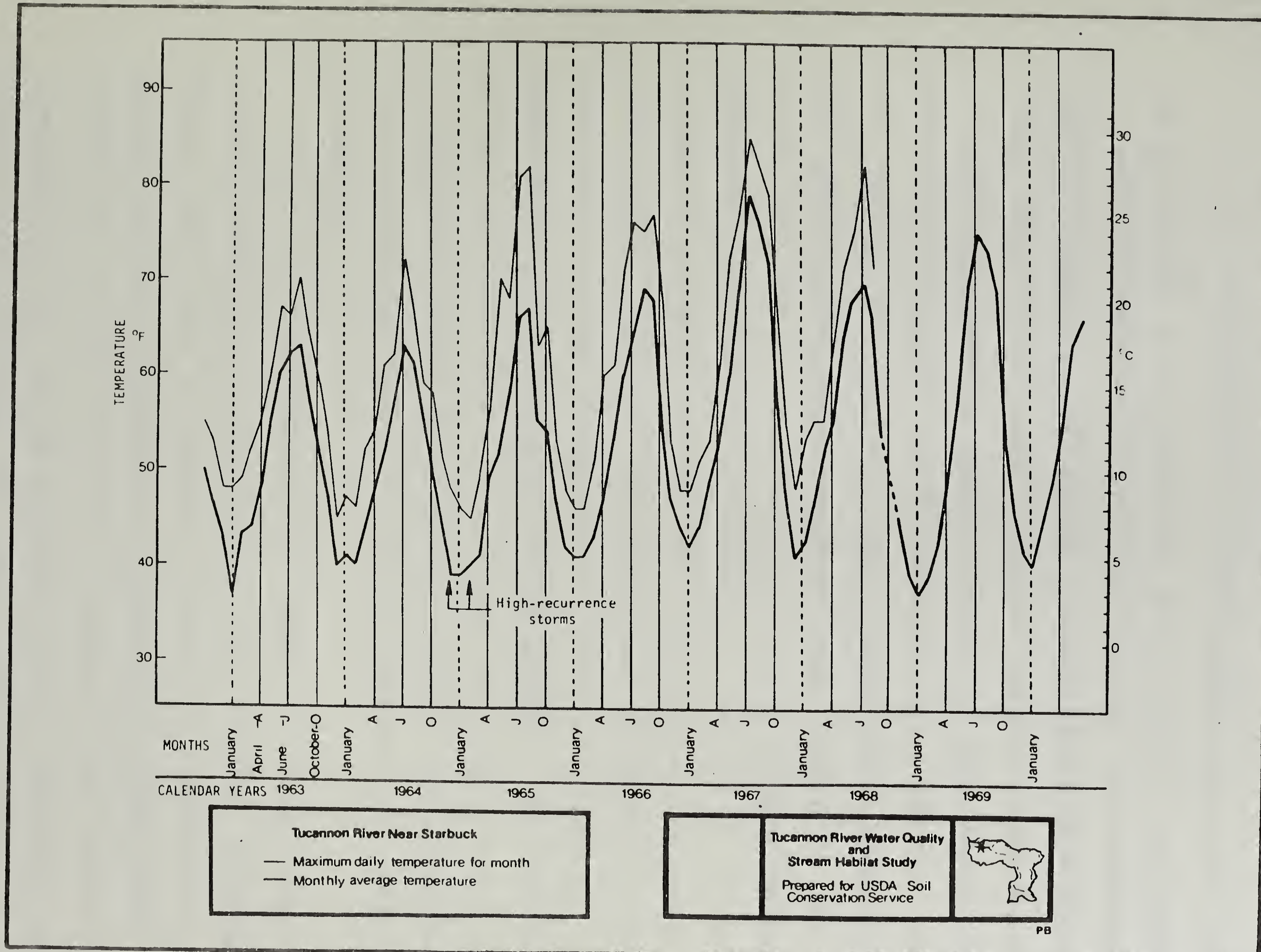

Figure 5.2. Seasonal and Year-to-Year Variations in Water Temperature, Tucannon River at Smith Hollow Road. Substantial variability is reported both in the maximum daily and mean temperatures for each month. Increases in channel width and damage to the riparian canopy following the floods of December, 1964 and January, 1965 may have resulted in an altered temperature regime (see chapter 6). Monthly averages computed by U.S. Geological Survey staff.

in a wider, less-shaded channel.

Temperatures in Pataha Creek also appear to be affected by the adjoining vegetation. Cultivation occurs to the bank for about six miles upstream of Chard Road. During the peak snowmelt period, maximum temperatures at Chard Road were substantially higher than at Pomeroy, where there is a partial canopy of streamside trees and shrubs. The distinction between the two stations, which commonly differed by 5°C on sunny days, are masked in part by the data from an unusual number of rainy, overcast days during April and May, 1980.

CHAPTER 6

BED CONDITIONS, TUCANNON RIVER

The bed characteristics of the Tucannon River influence the populations and distributions of all organisms in the stream. The bed is the environment within which the trout and salmon species pass their early stages of life. It serves a similar function for many of the aquatic invertebrate species. Some of the non-game fish, such as the dace common in the lower river, spend nearly their entire lives within the interstices of the bed. The bed surface provides the substrate upon which primary productivity developes; when unstable and broken up, a period of diminished productivity occurs while the bed is recolonized and normal growth rates resume. Similarly, the populations and types of aquatic invertebrate species during a given season are determined to a large extent by the nature of the bed surface. The distribution of the anadromous species found within the Tucannon River and the population levels the stream will support are influenced (both directly and indirectly) by the character and configuration of the bed.

The bed of the Tucannon River below the National Forest is formed predominantly of shifting bars and troughs. Upstream of Pataha Creek, these are composed primarily of cobbles and pebbles; pebbles and gravels predominate downstream of Pataha Creek. Interstices are often filled with a matrix of finer material, predominantly silt with an admixture of clay, finely-divided organic matter, and sand. The amount of matrix increases generally

in the downstream direction. The matrix is biologically significant in that it limits percolation and exerts an oxygen demand on the intragravel waters. It is hydrogeologically significant in that heavily-infilled horizons constrain the rate and direction of water movement through the coarser zones. Kelley and Li, in the course of this study, observed static levels of intragravel waters using mini-piezometers. They found several intragravel zones to have higher static heads of the flow in the stream. Water levels in the mini-piezometers were sometimes substantially different over distances of several feet. Finally, the finer material is of considerable geomorphic significance in that it "cements" portions of the bed, affecting the process of bar and channel formation. This condition is especially prevalent in the lower reaches of the river, downstream from Willow and Pataha Creeks, where heavily-indurated bars in portions of the low-flow bed are common. Extending up to several hundred yards, the individual indurated zones are typically 2 to 8 inches in depth, and are separated by comparably-thick horizons of more permeable material with much lower silt and clay contents. The indurated zones tend to be cohesive and hard; it is often difficult to break through them with a shovel. Channel migration and readjustment takes place either around these hard patches, or sometimes under and through them by a process of headward erosion.

Beds of this type are not common on a national or world-wide scale. The effects of these characteristics on channel form,

sediment transport, bed stability, and, finally aquatic habitat have not received much study in the Pacific Northwest or elsewhere. A wide range of tests and measurements were applied to the bed of the Tucannon. These include measurements of scour and fill by repetitive profiling of monumented cross-sections, measurements of the particle-size distribution of bed-surface material in each channel segment (pool, glide, riffle) after the winter and snow-melt seasons, quantifying cobble and boulder embeddedness, and exhaustive sampling and analysis of the bed composition. Results and interpretations of these analyses are summarized in this chapter.

Scour and Fill.

Changes in the configuration of the bed were described by four different approaches over the course of the Tucannon River study. Formal, systematic measurements of change were made at the five bed-monitoring sites (A,B,G, H,J; see Figure 1.1). Additionally, shifts in the bed can be traced from the cross-sectional data developed in the course of measuring streamflow at the six gaging stations. These two sets of measurements are largely of interest in geomorphic analysis, as they describe response of the bed to flow and relate changes in bed sediment storage to annual sediment yield. Additionally, two sets of measurements were made at locations in the channel deemed suitable for redds. The first of these were made by Don Kelley and his associates using scour columns--either ping pong balls or styrofoam chips connected with monofilament line. Finally, Chester Jahns, of USDA Soil Conservation Service project staff, measured scour and

fill relative to fixed marks on piezometers installed in artificial redds.

A good description of the frequency and extent of changes in the bed can be developed from the sequence of bed profiles developed from discharge measurements at the gaging station on the Tucannon River at the Krouse Ranch (Figure 6.1).* The bed profiles are developed from measurements taken at the exact same location--beneath a tape stretched tautly between a fixed pin on each bank. The profiles trace the following series of bed changes:

1. Formation and removal of a small bar on the left side of the channel during the minor storms of early winter.
2. Development of cobble bars during the storm peak of January 12, 1980.
3. Expansion of the right-bank bar into a major gravel bar during the storm peaks of January 14 and 15; complete scour of the smaller left-bank cobble bar between stations 10 and 17 also occurred.
4. Reworking and slight net depletion of the bar between January 21 and March 11, perhaps associated with the storm peak of February 18-19.
5. Increased bar development during the first week of the snowmelt season.
6. Minor reworking of the bar during the sustained high

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* These profiles are constructed from spot-depths observed while making a standard discharge measurement. Depths are determined using a wading rod at various distances from a permanent pin in the left bank. The water surface is assumed to be at the elevation read on the staff gage 110 feet downstream; because of changes in the bed both at the staff gage and measuring section, the water-surface elevation may be in error by as much as 0.3 feet.

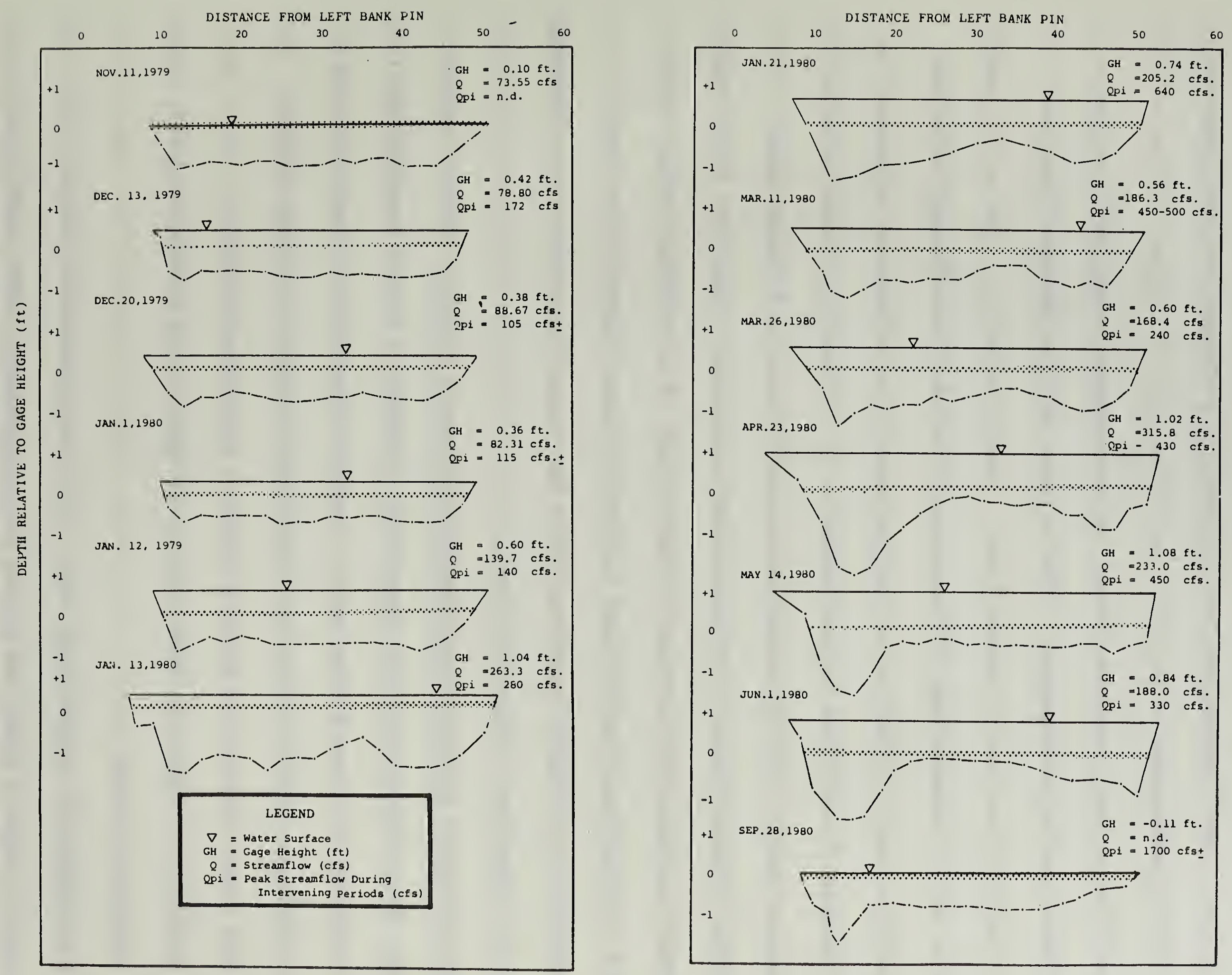

Figure 6.1. Changes in Bed Configuration At Krouse Ranch Gage, WY1980. Profiles are developed from some of the discharge measurements made at a monumented section. Minor changes in bed configuration occurred at flows of 100 to 200 cfs; major shifts occurred at flows exceeding 300 cfs.

flows of early May.

7. Major erosion and redistribution of the bar between June 1 and September 28, possibly related to the June 16 cloudburst.

The bed at this site, we observed, appears more changeable than at most other sites and gages. The river at the Krouse Ranch site is straightened and channelized. Additionally, the site is less than a mile downstream of the mouth of Willow Creek; the bed may, in part, change form as an adjustment to pulses of coarse sediment inflow from this major tributary. Finally, some of the changes are related to the complex hydraulics of a bridge pier about 70 feet downstream. It is clear, however, that at this one cross-section--just downstream of the head of a riffle--that much of the bed surface was mobilized several times during the year. This occurred at flows of 250 to 300 cfs, less than the mean monthly discharge for January, May and June.

Whole-Channel Analysis at Bed-Monitoring Sites. Three types of analysis were developed to describe changes in bed configuration. All are based on observations made during repetitive level-surveys of pools, glides, and riffles at the five bed-monitoring sties:

1. Net mean scour or fill within a cross-section,
2. Material added or removed from each riffle-pool-glide sequence, and
3. Net maximum scour and fill within a cross-section.

The five sites were first surveyed during March, then again in September. Changes measured, thus, are those of greatest importance

to habitat, including the spawning of spring-run salmon and steelhead, rearing of all fish, and the full annual cycle of aquatic plant and insect growth. At all sites, the effects of the snowmelt peaks on the bed are therefore measured. The peak discharge from the cloudburst of June 16 may also have altered the bed at the Krouse (B) and Helley Fletcher (G) bed-monitoring sites.

Methods: Each bed-monitoring site included a full sequence, including a consecutive pool, glide, and riffle. At most sites, pools were poorly-developed. Between six and ten cross-sections were established at each site, encompassing all three segments. End-points of each section were monumented with 4-foot lengths of ½-inch steel reinforcing bar driven into the ground so that 4 to 12 inches of steel project above the ground surface. Where possible, pins were placed at the January, 1980 high-water mark; the water-surface profile of this storm may be crudely reconstructed at each site from the elevations at the bases of the pins.

Net Mean Scour or Fill: Net mean scour or fill is the change in the mean elevation of the bed, averaged over one riffle, pool, and glide sequence. By definition material must have been removed from sections with net mean scour; conversely, addition of material must have occurred at sections which experienced net fill. As with other before-and-after surveys of flood effects, only the net result can be observed. The configuration of the bed in some cases may have been somewhat different at high flows; if so, changes in the bed associated with major storm crests are rapidly

effaced during periods of receding waters or minor storms.

Net mean scour and fill was relatively minor at the Camp Wooten and Hatchery sites (Table 6.1). The magnitude generally increased in the downstream direction.

Material Added Or Removed: The net inflow or outflow of bed sediment may be computed for the riffle/pool/glide sequence monitored at each site. This may be obtained from the net mean scour or fill at each section, integrated over its width and the channel for which it is representative. Detailed computations are presented in Appendix G.

The net change in bed storage described by this method increases in the downstream direction, as measured on a per-sequence or per-unit-length basis. This reflects the downstream increases in both width and in the magnitude of net scour and fill. Results are presented in Table 6.1 on a tons per channel mile basis. Generally, the seasonal bedload movements measured at gages near these locations were only several-fold greater than the material added or removed at the bed-monitoring sites. In other words, measured bedload yields during a year such as 1980 are comparable to the change in bed storage in the several pool/riffle/glide sequences upstream. It is clear that the bed is mobile, and at least on a year-to-year basis is the major source of coarse sediment moved by the river.

It should be recognized that this analysis is based on a very limited number of sites, and that the sites themselves were chosen by the biologists for other purposes. Additionally the

Table 6.1. Summary of Bed Configuration Changes, Tucannon River Bed-Monitoring Sites, WY1980 (Summary of Tables G-1 to G-5)

Code[a]	Name	Number of Sections	Net Mean Scour(-) or Fill(+) at Site[b] (feet)	Maximum Net Point Scour (feet)	Maximum Net Point Fill	Material Added(+) or Removed(-) at Site (ft^3)	(tons[c])	(tons/mile[c])
H	Camp Wooten	10	-0.02	-0.43	+0.48	-300	-14	-280
A	Hatchery Bridge	6	+0.01	-1.01	+1.27	+44	+ 2.6	+61
G	Marengo	6	-0.06	-1.15	+0.30	-930	-44	-1250
B	Krouse Ranch	8	+0.11	-1.45	+1.09	+1800	+83	+1400
J	Helley Fletcher	6	-0.18	-1.47	+0.44	-2200	-134	+3900

[a] Site designation, figure 1.)
[b] Difference in mean bed elevation, spring and fall surveys.
[c] Assumed bulk density of 120 lbs/ft^3.

Krouse and Fletcher sites were clearly affected by the June 16 storm, and had probably not completely adjusted from the effects of this unusual event. Nonetheless, we believe the results are broadly indicative and are useful for general planning purposes.

Maximum Point Scour or Fill: Maximum net point scour and fill define the greatest known disturbance of the bed during the period between surveys. At the downstream sites, the maxima at virtually every cross-section were associated with bar migration. More often than not, the maximum scour or fill at a site occurred at a cross-section in segments we considered to be poorly-defined pools. The changes are of the sort shown in Figure 6.1, although the particular transect described in the figure is within a riffle.

At the Hatchery site, maximum point scour was observed behind one of the large boulders placed in the stream as habitat-improvement measures by the Washington State Department of Game and Fish. The cross-sections were established in March, when these boulders were buried beneath a bar. We believe this bar formed during the unusual mid-January runoff event. Placement of the section was independent of the boulders, as we were not aware of their presence. They were uncovered during the period of maximum snowmelt, and were clearly visible at the end of May. The data suggest that the boulders can induce localized scour greater than that occurring elsewhere on the bed.

Scour At Locations Suited For Redds. The previous discussion considered whole-channel changes in the configuration of the bed. Because the bed is relatively mobile, it is logical to ask how

much scour and fill occurs at locations within the channel which might be chosen as redds. Both Don Kelley with his co-workers and the SCS staff addressed this question. They each monitored the extent of scour and fill at several locations where the biologists thought that salmonids might nest.

During December 1979 , scour-measuring devices were emplaced by associates at six sites from Camp Wooten to Powers Road. These devices were made from ping pong balls or styrofoam chips strung on monofilament line. They were buried 8 to 10 inches into bed. Very few of these devices could be relocated in early February 1980 , following the mid-January storms. They may have been scoured, or crushed or moved, or pulled out by ice and moving debris. Disappearance of these devices implies, but probably does not prove, that the bed may have been dilated during the January runoff events. Dilatancy of the Tucannon River bed to sufficient depths would threaten or destroy the redds.

The SCS staff observed net scour and fill during the April, 1981 freshet at 5 artificial redds at each of 5 sites (Table 6.2). A mark was scribed on thin metal piezometers projecting above at the time of installation. Where possible, changes in the general level of the bed nearby were noted in mid-May, when the redds were extracted.

Scour of a magnitude sufficient to wash away eggs in redds was observed only at site No. 1. Reportedly an important spawning area for fall-run chinook, this site is within an aggrading and shoaling reach of the river, within the tailwater influence of

Table 6.2. Observed Scour and Fill In Redd-Type Settings.[a]

No.	SCS Site Location	Sedimentologic Environment	Net Scour(-) or Fill(+), April to May, 1981 (feet)				
			Piez.1.	Piez.2.	Piez.3.	Piez.4.	Piez.5.
1.	Below Powers Rd. ("Near mouth")	Tailwater, deltaic deposition	-0.3[b]	-0.3	+0.3[b]	0.3	0
2.	At Powers Rd. ("Barton's")	Indurated gravels	n.d.	n.d.	0	0	0
3.	Fletcher Ranch	Clean gravel over heavy induration	n.d.	n.d.	n.d.	n.d.	n.d.
4.	Krouse Ranch	Mobile cobble and gravel bars	-0.23	-0.21	-0.29[c]	n.d.	n.d.
5.	Above Willow Creek ("DeRue Ranch")	Non-indurated	-0.05	-0.05	+0.05	+0.05	0

[a] Data collected by Paul Rogers and Chester Jahns, SCS staff.

[b] Piezometers found lying on surface. Actual maximum scour at these points may have been 0.5 feet or more.

[c] Maximum value. Actual net scour probably less.

Lower Monumental Reservoir. The bed at this site is finer and sandier than other portions of the channel. The maximum point scour may have been--and probably was--significantly greater than the observed net scour.

Little scour was noted at the sites where the bed is composed mainly of indurated gravels. It should be recognized that in these areas significant scour occurs only with failure of the entire indurated zone. The hydraulic threshold at which failure might be expected probably varies with the extent, thickness, and degree of induration. No data were collected to define such thresholds. Indirectly, complete loss of several redd-monitoring sites installed by Kelley and by the SCS staff indicate that the bed was mobilized to depths possibly affecting egg viability both during WY1980 and WY1981.

Bed-Surface Material.

The bed of the Tucannon River is heterogeneous, both with respect to its particle sizes and its horizontal zonation. In comparison with many other channels, the bed is markedly and irregularly stratified. Within the Tucannon channel, the greatest degree of differentiation is between the winnowed, coarser material at the bed surface, and the more heterogenous, generally finer material beneath. For initial analysis, we distinguished two populations:

1. The bed-surface material, which interacts with the flow, and which forms the substrate colonized by most aquatic plants and insects in the river; it is generally about 2 grain diameters in depth. Where the bed-surface material

is appreciably coarser and better-sorted than the underlying sediments, the bed may be considered "armored."

2. The material beneath the bed surface, which in the Tucannon River is often a sequence of distinguishable units, commonly 0.2 to 1.5 feet thick. The first population is described in this section, followed by a description of the materials below the surface.

Methods. The bed-surface population was sampled at six sites from Camp Wooten to Powers Road (Sites H,A,G,B,J,F,. Figure 1.1). These include the same sites used for measurement of bed configuration are are essentially identical to those used in much of the habitat assessment by biologist Don Kelley. A riffle and glide at each site were censused during late-September, 1980. Pools at these sites were not sufficiently developed to warrant separate consideration. The censusing procedure was tested at three of the sites in early-April, at the end of the winter storm period; these results are also presented.

The bed within each segment (riffle, glide) was sampled at 100 equally-spaced points. Ten longitudinal transects were established, with about 10 points at fixed distances along each transect. The particle immediately beneath each of these points was sampled. The size of particle was measured along its intermediate axis, and (if larger than 64 mm.) the embeddedness estimated. Particles smaller than 4 mm., which we find to be the lower limit of discrimination under field conditions, were assigned to a separate category informally labelled "sand and silt." This procedure is a minor elaboration on that of Wolman (1954), now in common use nationwide. Sample sizes of 60 to 100 particles are commonly recommended (Brush,

1961; Dunne and Leopold, 1980).

Results. Results of the bed-material size census are presented in Table 6.3. Particle sizes were almost wholly within the gravel (2.0-64 mm.) and cobble (64-256 mm.) range. Bed-surface area occupied by material finer than 4 mm. was negligible. Small boulders occurred in limited numbers, but generally did not exceed the 256 to 360 mm. size class; the larger material at the Hatchery site had been intentionally placed as a habitat-improvement measure. Particle sizes generally decreased in the downstream direction, but not as rapidly as in many other stream systems. Similarly, little difference in the sizes of bed-surface material between riffles and glides was observed; commonly, riffles are found to be 1.5 to 2 times coarser than glides.

Although there may be little inter-segmental difference in bed-surface material, changes over time appear to be substantial. The size distributions of particles on the bed surface at the Krouse and Powers sites became markedly finer between early April and late September. The locations of these two pebble counts were carefully established, and were repeated with an accuracy of several feet. Channel conditions at both sites had changed, with noticeable aggradation at the Krouse riffle and a change in the location of the main braid at the Powers site. Both occurred during June and are presumably related to the cloudburst crest of June 16, 1980. There was little change at the Camp Wooten site, which did not sustain a major snowmelt or cloudburst crest.

The central portions of the bed-surface distributions at the

Table 6.3. Particle Size[a] Descriptors of Bed-Surface Material, Spring and Late Summer, 1980

Tucannon River Basin

	Spring Sampling				Late Summer Sampling											
	Powers Road	Krouse Ranch	Camp Wooten		Powers Road		Fletcher Ranch		Krouse Ranch		Marengo		Hatchery		Camp Wooten	
	Riffle[b]	Riffle/Glide	Glide	Riffle	Glide	Riffle	Glide	Riffle	Glide	Riffle	Glide	Riffle	Glide	Riffle	Glide	Riffle
Date	4/6	4/7	4/10	4/10	9/25	9/25	9/25	9/25	9/30	9/30	9/27	9/27	9/28	9/28	9/29	9/29
Number	156	132	60	72	92	66	200	100	64	100	94	102	120	100	80	80
% < 4mm[c]	0	0	0	0	1.1	0	0	0	0	0	0	0	0	0	0	0
Sizes (mm)																
Dmax[d]	180	180	360	256	128	128	256	360	90	90	256	180	512	360	256	256
D_{95}[e]	139.2	155.4	205.1	235.6	66.3	109.2	79.3	210.9	79.9	90.5	191.8	191.3	224.4	278.2	235.6	178.5
D_{84}	103.9	116.1	137.2	146.1	42.3	76.1	59.3	90.5	68.6	66.3	127.3	128.0	155.4	191.3	168.9	119.4
D_{65}	75.1	87.4	98.4	97.7	34.4	55.7	42.9	64.5	56.1	52.0	85.0	93.8	112.2	135.3	136.2	97.7
D_{50}	59.7	72.6	83.3	79.9	27.9	45.8	35.5	45.3	47.5	44.7	72.6	86.8	87.4	107.6	109.9	84.4
D_{35}	46.1	64.1	71.0	68.6	20.8	37.3	29.3	34.4	36.8	36.8	57.7	62.2	68.6	85.0	84.4	67.6
D_{16}	28.7	41.0	56.1	58.1	14.0	25.6	22.1	24.2	24.2	27.9	39.2	43.4	49.2	63.6	64.1	52.0
D_5	17.0	25.6	-	50.6	8.6	16.6	16.9	16.0	12.6	20.8	21.9	23.5	25.3	45.3	39.5	31.5

a/ All sizes refer to the "b", or intermediate, axis of the sampled bed particle.

b/ Designation assigned by observer in field.

c/ The percentage of bed area covered by sand (approximated by percent smaller than 4mm -- the smallest measurable size in the field) is often a sensitive index of relative siltation. Absence of sand on the bed surface does not in this case imply good habitat conditions; rather, it reflects the uniformly high velocities (and high bed shear), as well as the relative dearth of sand in this geomorphic environment.

d/ The lower limit of the size class in which the largest sampled particle would be included; multiply this value by 1.414 for upper limit.

e/ Size, in millimeters, for which the subscripted percentage is finer. For example, 84 percent of the Powers Road sample of April 6 was finer than 103.9mm.

Krouse and Powers sites exhibited a 50 to 75 percent decline in particle sizes. This magnitude of change is unusual in relatively large streams such as the Tucannon River; it is typically associated with major depositional events, such as those produced by runoff from large wildfires, high-recurrence floods, or extensive point-sources of sediment. The data are extremely limited--two pairs of pebble counts in reaches known to be more changeable than other portions of the river. Nonetheless, the fact that a cloudburst runoff peak of relatively minor overall recurrence (perhaps 1.5 years) might induce significant changes in the bed surface is another indication of general bed instability and focuses attention on cloudbursts as an important influence on summer and fall habitat values.

Embeddedness of cobble- and boulder-sized material was measured at each of the bed-monitoring sites. These larger particles generate turbulence, which in turn provides shelter and cover to most fish species using the Tucannon River. Relatively finer material (generally sand and silt) can accumulate in these zones of irregular flow and generally quieter water. In many streams, the amount of habitat is inversely proportional to representative embeddedness (Bjornn and others, 1979: Kelley and Dettman, 1980).

We estimated the embeddedness of all particles larger than 64 mm. sampled during the census of bed-surface material. Embeddedness was defined for the purpose of this study as the proportion of the particle's depth to which it was embedded in much finer material. In the channel of the Tucannon River, virtually the

entire bed surface is composed of angular coarse gravel and cobble, often closely-packed or interlocking. The particles are effectively incorporated in a network of similar-size material. The voids and turbulence cells which provide rearing habitat in other streams are smaller and rarer in the Tucannon River, not so much due to burial by finer debris (sedimentologically, "matrix"), but by incorporation in a closely-packed network of similar-sized clasts ("fabric").

Mean embeddednesses of cobble- and boulder-sized material at the six bed-monitoring sites are summarized in Table 6.4. These values are averages of field estimates of "matrix" embeddedness, consciously excluding the effects of the close-packed bed fabric. Mean embeddedness is low throughout the Tucannon River, even though there are relatively few available eddies or other turbulent niches. We question whether embeddedness is a useful measure of habitat value in the river, or in other streams of southeastern Washington with similar types of beds. The most informative individual datum apparent in this analysis is the seasonal decrease in embeddedness at Camp Wooten, which may be interpreted as the outgrowth of flushing of fine sediment deposited during the unusual winter storms by the clear snowmelt waters.

Bulk Bed Material.

Sediments beneath the bed surface are often referred to as "bulk bed material." In the Tucannon River, these are composed of distinct horizons, with textures, thicknesses, degrees of induration and water-bearing properties which vary radically. To a certain extent, bed heterogeneity is a characteristic of braided streams. The unusual size distribution of material in the river and the high suspended sediment transport rates both add to the

Table 6.4. Mean Embeddedness[a/] of Bed-Surface Material, 1980

Tucannon River Basin

Habitat Survey Site				Sample Size		Embeddedness	Surface Particle Sizes		
Designation[b/]	Name	R/G[c/]	Date	Total	>64mm	>64mm	D_{50}	D_{84}	Dmax
F	Powers Road	R	4/6/80[d/]	156	72	0.43	59.7	103.9	180-256
		R	9/25/80	66	17	0.12	45.8	76.1	128-180
		G	9/25/80	92	11	0.25	27.9	42.3	128-180
J	Fletcher Ranch	R	9/25/80	100	33	0.32	45.3	90.5	360-512
		G	9/25/80	200	25	0.33	35.5	59.3	256-360
B	Krouse Ranch	R	4/7/80[d/]	132	79	0.20	73.1	116.1	180-256
		R	9/25/80	100	19	0.12	51.8	66.3	90-128
		G	9/25/80	64	16	0.23	47.5	68.6	90-128
G	Marengo	R	9/27/80	102	65	0.17	86.8	128.0	180-256
		G	9/27/80	94	55	0.16	72.5	127.3	256-360
A	Hatchery	R	9/28/80	100	84	0.17	107.6	191.3	360-512
		G	9/28/80	120	83	0.15	87.4	155.4	512-725
H	Camp Wooten	R	4/6/80	72	53	0.23	79.9	146.1	256-360
		R	9/28/80	80	55	0.12	84.4	119.4	256-360
		G	4/6/80	60	45	0.25	83.3	137.2	360-512
		G	9/28/80	80	68	0.19	109.9	168.9	256-360

a/ Embeddedness is defined as the proportion of a particle's depth to which it is embedded in the channel by appreciably smaller material.

b/ Symbol designating site on the location map.

c/ Distinguished in field; riffle and glide refer to relatively steeper and less steep segments of the braided channel and should not be equated with features of the same name in meandering channels.

d/ Substantial change in channel configuration at this riffle precludes valid comparison between April and September measurements.

complex composition of the bed.

Central to any discussion of the bed composition is the bi-modal size distribution of available sediment in the Tucannon watershed. This is almost wholly due to the regional geology. The Columbia River Basalts primarily weather to gravel chips and larger fragments, or to clays and fine silts. Very little sand or fine gravel is generated in the process of decomposition. The deposits of loess which mantle most of the lower two-thirds of the watershed are composed almost entirely of silts,* and weathers to silt- and clay-sized material. Prior studies of the region indicate that the percentage of sand-sized material in the sediment loads of Touchet basin streams originating in the mountains may be as high as 10 to 12 percent, while those draining the loess-covered hills generally transport less than 5 percent sand. Streams in the Palouse River basin, similar in many respects to the Tucannon River and other southeastern Washington streams, transport significantly greater amounts of sandy material due to different geologic influences. An important subordinate factor contributing to the relative dearth of sand and fine gravel is that the steep, braided streams readily transport any material of these sizes delivered to them.

Sand-deficient environments are rare. There has been virtually no study of streams with beds containing almost solely coarse and very fine material. There are two immediate consequences for this study:

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* The loess is thought to have been deposited from the west, and exhibits a tendency to fine eastward. It is coarsest in the Walla Walla area, with sand-sized particles much rarer in Columbia, Garfield and Asotin Counties.

1. As the system contains almost no sand, analytic approaches developed elsewhere, especially in sandy areas, may not be useful or applicable. The difficulties discussed in the previous section with regard to applying the measure of embeddedness to the Tucannon River are a case in point. Some unfamiliar conditions, such as the indurated bed horizons, should be expected.
2. Because the sediments are strongly bimodal in their size distribution, use of tests and procedures based on an assumption of lognormal distribution may or may not be appropriate. This affects, in particular, interpretations of habitat value or hydraulic properties based on particle-size distributions.

Thus, many of the approaches and procedures used in describing the composition of stream beds and evaluating their value as aquatic habitat may not be applicable to the Tucannon River. Any analysis developed in the course of this study will, however, probably be useful in interpreting conditions throughout the Blue Mountain region and in other stream systems lacking sand.

Finally, beds of braided streams have different sedimentological properties than those found in meandering channels. They tend to be more uniform across the stream, although at a given spot a braided stream bed is likely to have finer and more variable stratification. The particle-size distributions of the beds of braided streams also tend to be more uniform over long distances along the length of channel. We believe that an appropriate sampling

strategy in braided channels is to collect a greater number of samples at a smaller number of sites, distinguishing the different depositional units found at given points.

A reconnaissance sampling was conducted in September, 1980. Staff members from SCS and The University of Idaho conducted a detailed freeze-core sampling program in March and May, 1981.

Reconnaissance Analysis. The Tucannon River bed was studied and described during WY1980 using a variety of reconnaissance methods. In a companion report, Don Kelley and his associates describe their initial approach to measuring the movement of oxygen, water, and salts through the intra-gravel environment.

Also on a preliminary basis, two samples of the bed beneath the surface were drawn from each of the six bed-monitoring sites during WY1980. This preliminary study was undertaken as a pilot for a more comprehensive freeze-core sampling program, and also to identify whether greater amounts of sand might be found in the bed.

Methods: At each site, one sample was collected from the areas chosen by the biologists as being suited for spawning. Another sample was collected from a more hydraulically-active portion of the channel, often from mid-stream. The bed-surface material was stripped from an area approximately 15 inches square, to a depth of about two diameters of the dominant particles sizes at the surface. A six-inch thin-walled sampler* was rotated as

* After trying a variety of 6-inch samplers, we chose to use a simple 2-pound coffee can to collect bulk bed samples. The coffee can allows greater control while driving and extracting the sample than do more complex devices. With practice, the metal plate can be inserted under the can to form an air-tight seal; the sampler may then be extracted and inverted prior to decanting. Large amounts of silt and clay are inevitably released from the bed during the

gently as possible into the bed, then driven in as far as practicable, generally 4 to 6 inches. Samples were extracted by digging around the sampler, inserting a metal plate beneath the open bottom, then removing the can and plate from the bed. Pinholes were drilled into the base of the can, allowing the sample to drain. Samples were oven-dried and sieved at the HEA laboratory.

Results: Size distributions of bed-core samples taken at each of the habitat sites are shown in Table 6.5. The distribution of sizes at the Powers, Fletcher, and Krouse sites are similar to samples extracted the following year at the same sites using freeze-core procedures. An important exception is that the silts and clays, as expected, are probably under-sampled.

Coarse gravel (16-64 mm.) predominate beneath the bed surface throughout the Tucannon River channel. Differences between sites, on the basis of this very small sample, appeared to be less than those between different environments at each site. Generally, the spawning areas contained more sand and finer material than did the mid-channel sites. In the coarser half of the distribution, there was little noticeable difference between the central portions of the channel and those throught to be suitable for spawning.

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driving and extraction in hard, large-caliber material composing the bed of the Tucannon River. Hence, samples collected this way cannot be used in determining the proportion of the bed composed of silt, clay, or finely-divided organic debris. They are suitable, however, to establish the overall composition of the bed for most sedimentologic and geomorphic purposes.

Table 6.5. Size Distributions of Bed Core Samples

Tucannon River Basin, September, 1980

Habitat Site		Sample		Percent Finer		Size Distribution (mm)[b/]								
Designation[a/]	Name	Description	Dry Wt. (g)	.063mm	1.0mm	D_5	D_{16}	D_{35}	D_{50}	D_{65}	D_{84}	D_{90}	D_{95}	Dmax[c/]
H	Camp	Head of bar, H6[d/]	982.3	.5%	6.6%	0.76	7.0	16.5	22.6	28.1	45.9	47.8	50.2	45-62.5
	Wooten	Side channel, H6	2058.5	.1%	2.0%	7.2	15.4	25.9	36.7	45.5	64.0	49.1	51.9	45-62.5
A	Hatchery	Head of bar, A2	1995.6	.2%	2.1%	2.4	6.1	10.3	16.5	25.9	32.6	33.8	35.5	32-45
		Adjacent to next-to-lowest piezometer, A4	2606.3	.2%	2.7%	2.1	7.2	14.9	27.4	37.0	47.5	48.5	50.2	45-62.5
G	Marengo	Mid-channel, G2	1138.0	.04%	.4%	3.2	8.2	13.9	22.6	33.3	36.2	38.1	40.2	32-45
		Bar, adjacent to third standpipe, G2	1509.7	.2%	4.2%	1.3	5.8	12.6	21.3	66[e/]	73[e/]	77[e/]	82[e/]	62.5-90
B	Krouse	Mid-channel, B2	1302.6	.1%	.5%	8.9	15.5	22.6	29.0	32.8	35.2	36.7	38.5	32-45
		Head of left bank bar near upper standpipe, B4	1348.2	.1%	.7%	4.3	9.5	15.3	29.8	33.1	35.5	36.7	38.0	32-45
J	Fletcher	Main channel near standpipes	1373.4	.04%	.22%	8.3	22.3	29.0	35.0	41.9	48.5	49.5	51.9	45-62.5
		Bar, middle of upper standpipe cluster	1628.9	2.2%	4.4%	1.2	5.2	9.6	12.7	15.5	23.4	45.2	47.8	45-62.5
F	Powers	Bar, approx. 125 ft. u/s of bridge	1286.1	4.4%	13.0%	0.08	1.3	11.3	17.3	25.9	34.0	35.5	37.7	32-45
		Mid-channel, approx. 100 ft. u/s of bridge	1322.0	.05%	0.18%	12.8	19.2	30.6	48.5	65[e/]	76[e/]	83[e/]	88[e/]	62.5-90

a/ Symbol on location map.

b/ Size, in millimeters, of the fraction of the sample finer than the subscripted percentile. For example, the median grain size for the head of bar sample at Camp Wooten is 22.6mm.

c/ Lower and upper limits of size class of largest single particle.

d/ Symbols such as H6 or A2 identify the level-surveyed cross-section at which samples were taken.

e/ Larger values are approximate; the several largest particles comprise much of total sample weight.

Freeze-Core Sampling Program. A more intensive, systematic description of the bed was undertaken in the spring of 1981. Principal sampling objectives included:

1. Describing the sedimentary structures and stratification of the bed in the Tucannon River. This can be done only by using freeze-core procedures.
2. Defining the particle-size distribution of the bed, distinguishing between material on the surface and at various depths beneath it.
3. Determining the rate at which fine sediment accumulates in redds.
4. Documenting the relationship between the presence of fine sediment and diminished dissolved oxygen in redds.
5. Investigate whether the finely-divided organic matter prevalent in the Tucannon River exerts a significant oxygen demand on the intra-gravel waters.

The sampling program and the initial three sets of questions are discussed in this report. The fourth and fifth issues are addressed in the companion report by Don Kelley and Stacy Li.

In the freeze-core sampling process, a portion of the bed is congealed and extracted. Three metal probes are driven into the bed in a triangular pattern to a depth of about 18 inches. These are then chilled with compressed carbon dioxide. Material within the triangle, plus other material clinging to the probes, is then extracted.

Two types of samples were collected from the bed:

1. Artificial redds built by SCS staff at locations suitable for spawning; these were constructed in mid-March, and removed in mid-April.
2. Adjacent portions of the bed which had not been winnowed or otherwise altered by redd-building activity.

Generally, 5 artificial redds and two "undisturbed" sets of samples were collected at each study site. Both types of samples were collected, then separated into depth intervals of 0 to 7 inches, 7 to 14 inches, 14 to 20 inches. These were informally labelled "top," "middle," and "bottom."

Sampling was conducted at five sites along the lower half of the river. The site furtherest downstream, below Powers Road, is in a deltaic depositional environment within the tailwater influence of Lower Monumental Reservoir. Samples were also collected at Powers Road, (site F, figure 1.1) at the Kelley Fletcher Ranch east of Starbuck, (site J) at the Krouse Ranch (site B) and at the De Rue Ranch, two miles south of the Highway 12 bridge.

The De Rue site is above Willow Creek, upstream of most sediment input from the agricultural portions of the basin. Several steep unnamed tributaries immediately upstream had major flashfloods during the June 16, 1980 cloudburst. Much of this material, including much gravel, was deposited in the Tucannon River. The effect, if any, of this imposed additional load on the bed composition is unknown. The Krouse site is below the confluence of Willow Creek. Bed composition was clearly affected by extensive delivery of gravel from this tributary in June, 1980. Another, smaller cloudburst affected Willow Creek during the sampling

period. The three other sites are affected by the large loads of silt and clay introduced from Pataha Creek, Smith Hollow, and other tributaries.

Methods: Artificial redds were constructed using hand tools with back-and-forth movements considered similar to those of spawning salmonids. Mini-piezometers of the type described by Kelley and Li were installed in each redd. Backfilling was, again, done with motions throught similar to those of the spawning fish. When the original bed level was restored, the piezometer was scored to mark the level of the bed. Measurements of dissolved oxygen and other constituents of the intra-gravel waters were periodically made through the mini-piezometer during the next two months.

Cores were extracted using a three-probed freeze-core sampler provided by the University of Idaho through the assistance of Dr. T. C. Bjornn. Immediately prior to extraction of the artificial redds any net scour or fill relative to the inscribed mark was noted. Upon extraction, the gross appearance and stratification was described. The core was separated by depth class into samples. Occasionally, portions of the core did not freeze, and were lost upon extraction; any significant losses were noted.

Bagged samples were taken to the University of Idaho, when the top and middle samples were dried, sieved, and weighed.

Results: Careful field descriptions were recorded by Paul Rogers and Chester Jahns of the SCS staff. Most cores contained three to five visibly-distinct sedimentologic units, distinguishable by texture or by the extent and type of interstitial matrix. Units ranged from 1 to 14 inches in depth, but nearly all had

apparent thicknesses of about 2 to 10 inches. Median thicknesses ranged from 4 to 6 inches, or slightly less than the sampled depth interval.

Many abrupt changes were noted in the size composition. Often, these were based solely on the character of the interstitial fill, which appeared to have developed following deposition of the unit. An informal field sketch of bed sedimentology in one artificial redd at the De Rue site is shown in Figure 6.2.

The mean composition of the bed by depth interval at each site is presented in Table 6.6. A distinction is made in the table between the artificial redds and the nearby portions of undisturbed bed from which cores were collected. This tabulation excludes samples which were seriously biased by losses during extraction, based on the sample weights and attached field observations. Most samples exceeding 5 pounds were included in the tabulation.

Discussion: The bulk bed material of the lower reaches of the Tucannon River is composed primarily of coarse gravels and fine cobbles.

A second and very distinct component of the bed is composed of silt and clay, much of which apparently enters the bed after the sedimentary fabric is established. The two components are separate populations, with different sources and characteristics. They are present in weight proportions of about 90 to 95 percent and 5 to 10 percent, respectively, of the bed sediment.

A necessary first step in assessing these findings is evaluating the validity of the samples. In our opinion the freeze-core

Table 6.6. Variations in Mean Particle Sizes of Bulk Bed Material At Five Sites With Depth and Age of Sample Tucannon River, Spring 1981 a/

Site No.	Site Location	Size b/ Percentile	Mean Size Distribution of "Redds" c/ Top 7"	Mean Size Distribution of "Redds" c/ Middle 7"	Mean Size Distribution of Undisturbed Bed d/ Top 7"	Mean Size Distribution of Undisturbed Bed d/ Middle 7"
1	Near Mouth		n=3	n=3	n=2	n=2
		D_5	1.43	0.13	0.24	0.12
		D_{10}	3.16	0.62	1.10	0.31
		D_{16}	5.40	1.59	4.38	1.76
		D_{35}	10.78	6.82	11.45	6.40
		D_{50}	14.23	11.70	15.59	10.18
		D_{65}	17.87	16.80	19.39	14.94
		D_{84}	25.06	25.97	26.56	23.08
		D_{90}	29.09	30.74	29.76	26.87
		% <.074 mm	1.3%	5.0%	2.2.%	5.0%
2.	Powers Road		n=4	n=5	n=2	n=2
		D_5	1.03	0.16	0.45	0.30
		D_{10}	6.98	0.63	1.68	1.17
		D_{16}	14.96	2.75	6.07	2.70
		D_{35}	25.05	13.84	23.72	13.88
		D_{50}	35.04	25.56	36.62	28.84
		D_{65}	45.02	36.86	53.76	78.52
		D_{84}	61.01	54.27	87.12	94.82
		D_{90}	67.58	62.65	96.78	105.94
		% <.074 mm	2.0%	3.8%	2.5%	3.6%
3.	Helley Fletcher Ranch		n=4	n=5	n=2	n=2
		D_5	5.06	0.16	1.37	0.20
		D_{10}	12.52	1.16	3.50	2.00
		D_{16}	16.35	4.86	6.24	7.42
		D_{35}	25.68	15.76	15.40	18.76
		D_{50}	31.93	22.97	22.13	27.44
		D_{65}	39.59	31.99	33.06	39.80
		D_{84}	51.09	46.72	47.28	58.94
		D_{90}	55.56	53.64	56.74	64.86
		% <.074 mm	1.2%	3.8%	1.4%	4.0%
4.	Krouse Ranch		n=5	n=4	n=2	n=2
		D_5	0.31	0.24	0.35	0.26
		D_{10}	8.85	1.66	1.01	0.88
		D_{16}	15.67	4.83	2.74	2.91
		D_{35}	30.65	23.62	13.82	15.49
		D_{50}	45.51	34.84	21.68	29.90
		D_{65}	58.58	53.27	33.88	56.42
		D_{84}	80.93	66.64	48.55	71.60
		D_{90}	86.17	74.74	68.96	77.02
		% .074 mm	2.7%	3.1%	1.4%	2.2%
5.	De Rue Ranch		n=2	n=5	n=2	n=2
		D_5	0.35	0.40	3.01	1.08
		D_{10}	3.16	1.58	5.98	2.73
		D_{16}	5.63	4.19	8.32	5.19
		D_{35}	12.05	9.56	13.90	14.46
		D_{50}	16.63	24.50	17.15	23.50
		D_{65}	21.34	39.04	22.50	32.70
		D_{84}	29.81	53.27	35.41	51.42
		D_{90}	34.02	61.01	43.90	58.90
		% <.074 mm	1.0%	1.3%	0.1%	0.9%

a/ Field description and sample collection by Paul Rogers and Chester Jahns, USDA SCS staff; particle-size analysis at University of Idaho College of Forestry Wildlife and Range Sciences.

b/ Percentile finer than. Example: D_{10} identifies the size, in millimeters, for which 10 percent of the sample is finer.

c/ Artificial redds constructed at locations in the channel deemed suitable for spawning. "Redds" built by SCS biologists in mid-March, 1981, then extracted during mid-May.

d/ Size distributions of undisturbed bed material near the artificial redds.

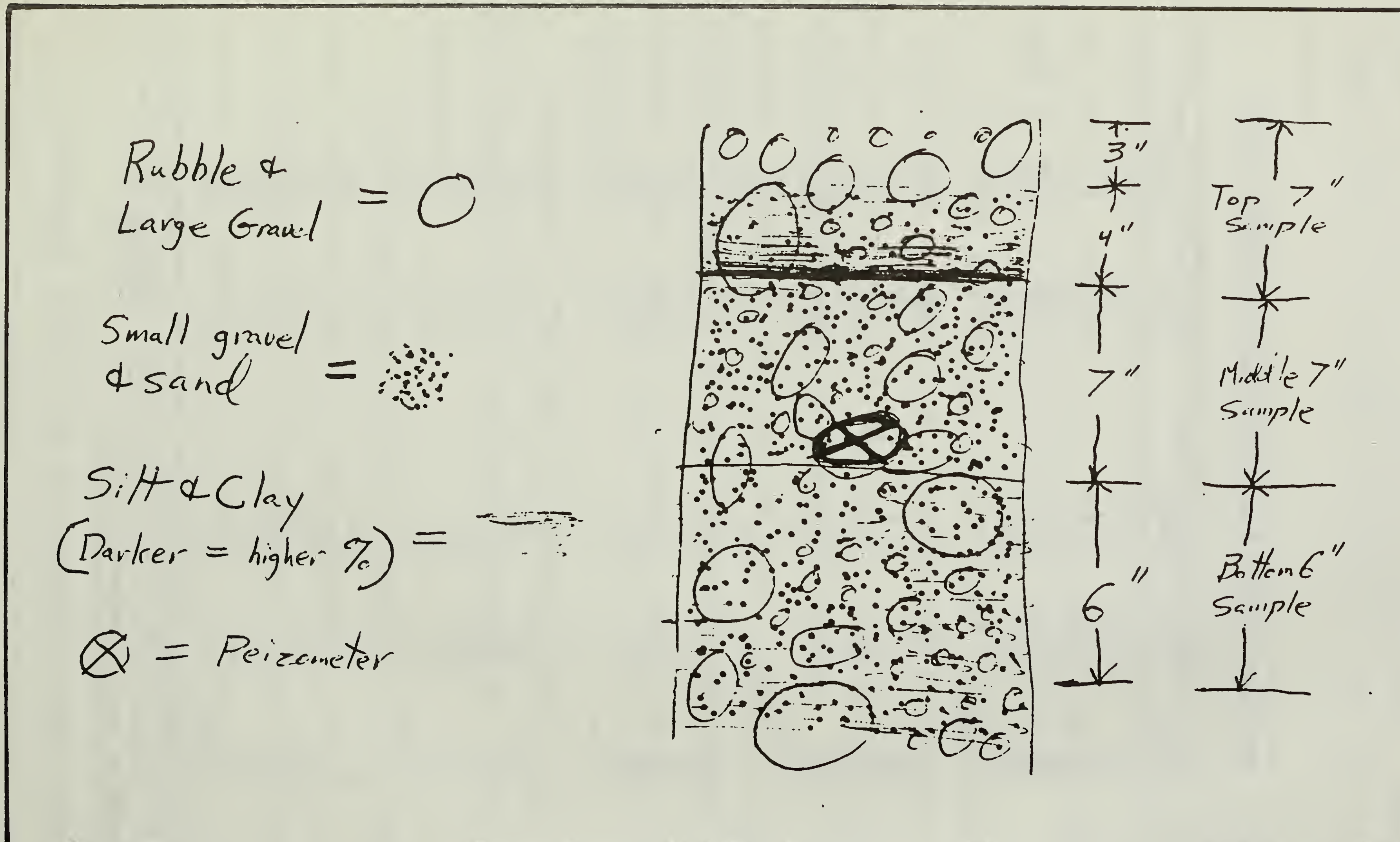

Figure 6.2. Informal Field Sketch of Infilled Artificial Redd At De Rue Site. Location of site is above Willow Creek. Piezometer marks base of zone cleared of fine material during redd construction. Sketch from field notes of Paul Rogers.

process is the only one which can adequately sample the two populations present in the bed. It is clearly a superior means of collecting representative portions of the bed from the Tucannon River and similar streams. It should be understood that, as with any sampling method, some bias is introduced; familiarity with these tendencies is important, especially in comparing samples collected by different methods. We believe that the freeze-core procedure may over-sample the largest size classes, as these are more likely to come in contact with and adhere to the probes. It is also sometimes difficult to freeze matrix-free gravel zones in an otherwise-silty sample; these tend to be lost on extraction. Similarly, some of the matrix is dislodged and lost as the probes are inserted into the bed. Nonetheless, we believe that these data should be considered a valid and reproducible description of the bed as it was sampled.

The indurated horizons, and some of the process affecting their formation by gradual interstitial infilling, can be analyzed from the sampling results. Samples 42, 43, 46 and 47, all from the Helley Fletcher Ranch site, were chosen for this analysis. These samples are described in Table 6.7.

Development of indurated horizons, presumably by gradual filling of interstices, is widespread in the Tucannon River and many of other southeastern Washington streams. Differences in the composition of "clean" and silt-filled gravels are shown in Figure 6.3, based on the data in Table 6.7. The figure presents the particle-size distribution, by weight, on a logarithmic probability graph. Many sediments in stream environments are

Table 6.7 Descriptions and Size Distributions of Characteristic Bed-Sediment Horizons, Tucannon River Bed, May. 1981

Location and Identifiers	Field Description[a/]	Size of Weight-Distribution Percentiles					
		D_5 (mm)	D_{10} (mm)	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{90} (mm)
I. Artificial redd[b/] Sample 42: Top 7 inches	"This entire subsection is compsed of clean, washed gravel with little or no interstitial fines at all."	14.0	19.47	23.17	39.62	62.98	67.61
Sample 43:[c/] Middle 7 inches	Rapid transition to zone of high silt percentage, plus moderate small gravel and decreases in silt to 10" depth. From 10" to 14", interstitial material is mainly small gravel and sand... "Our subsections basically broke this sample right at transitions between layers. A very good sample for having subsections representing the changes with depth in the redd."	0.25	3.25	8.75	26.51	56.35	63.07
II. Undisturbed bed Sample 46: Top 7 inches	Clean gravel to depth of 2" to 4". Grades abruptly to zone with moderately high sand and small gravel, plus some silt.	0.20	0.63	2.44	18.21	45.45	57.56
Sample 47:[c/] Middle 7 inches	Top inch identical to above. At 8", transition to layer almost totally lacking in sand. Interstitial material is extremely high in silt, with some small gravel	0.05	2.21	9.90	27.79	58.99	64.90

a/ Descriptions by Paul Rogers and Chester Jahns, Soil Conservation Service staff.
b/ Described in text.
c/ Bottom cores not analyzed at these locations.

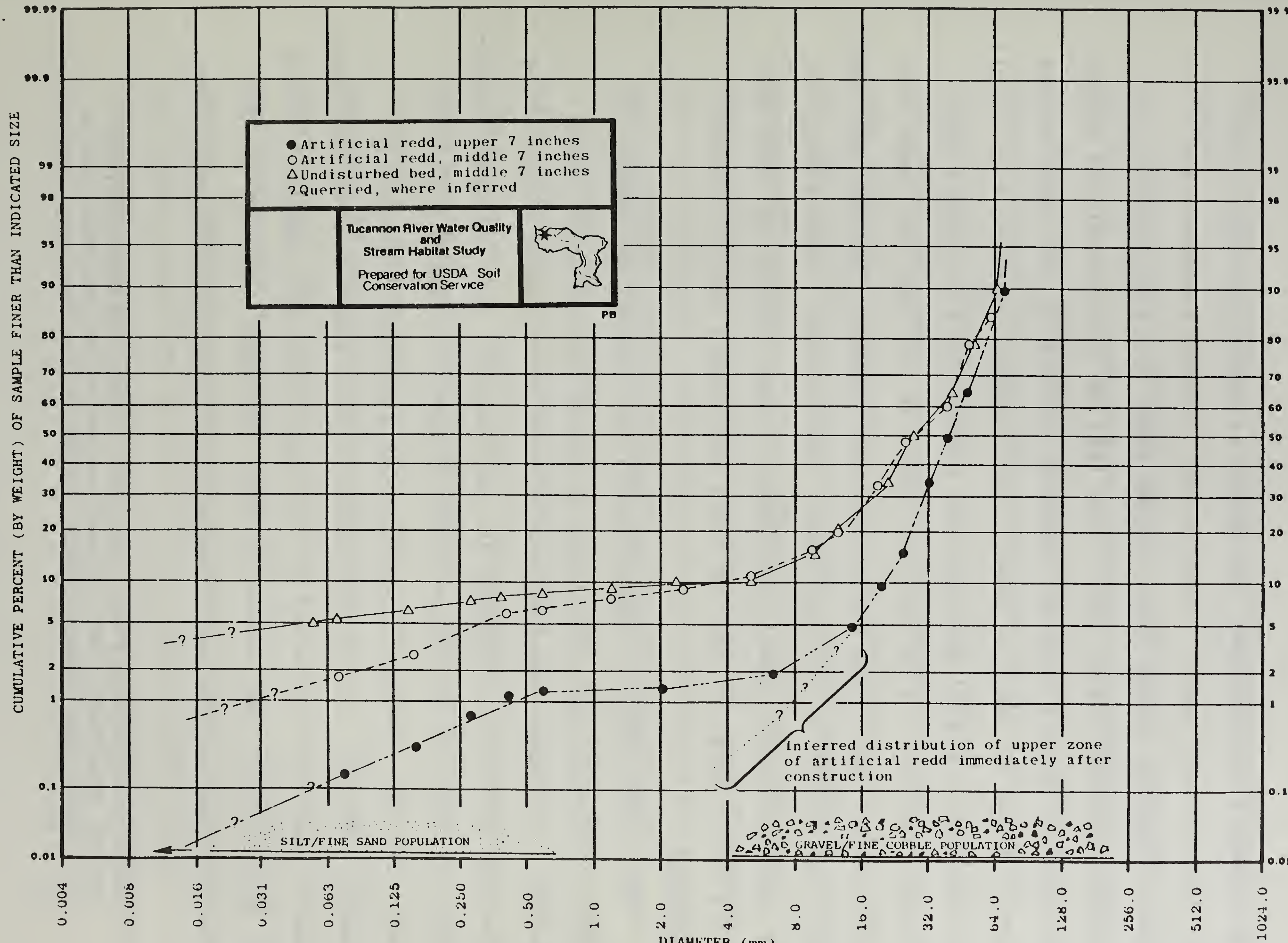

Figure 6.3. Particle-Size Distribution of Artificial Redds and Undisturbed Substrate, Tucannon River Below Pataha Creek at Helley Fletcher Ranch. Data from Table 6.7; sample 46 omitted for clarity.

log-normally distributed, and appear as nearly-straight lines on plots of this type. Often as not , stream sediments are skewed slightly toward their coarse ends, and thus tend to plot slightly concave upward and to the left on log-probability graphs. Two separate populations are apparent in each of the three weight distributions of samples shown in the figure. Most of each sample is composed of gravel and smallest cobble, with a typical near-straight pattern. A second population of silt and fine sand comprises about two to ten percent of each sample. The silt and fine sand also appear to be lognormally distributed. Separating the two populations are nearly-horizontal lines through the sand and fine gravel sizes, reflecting their deficiency in the Tucannon watershed.

The figure also is suggestive of the gradual processes related to interstitial infilling, by which the indurated zones develop. Following construction of artificial redds, very little fine sand and silt is present in the gravels. The inferred distribution of sizes in the upper zones is shown in Figure 6.3* With time, silt and fine sand accumulate in the voids between the gravels. Gradually, the percentage of silt and fine sand increases toward a maximum, reflected by the undisturbed bed sample. During the March through May period in 1981, the upper zones of the bed remained freer of the infilling material, presumably because they

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* Curvature for the finer portion of this distribution is scaled from data for a freshly-constructed chinook red in the South Fork Salmon River, cored in its entirety (Platts _et. al_. 1979).

were scoured, dilated, or otherwise reworked by successive flood crests.

These general findings appear to hold true even where the samples did not coincide with individual sedimentation units. Throughout the lower half of the Tucannon River, the artificial redds differed from the undisturbed bed in one key respect (Table 6.6). The proportion of fine sand and silt was lower in the artificial redds, but appreciably so only for the upper zone. Deep portions of the redds--where the biologists believe eggs are most likely to be deposited--were indistinguishable from the corresponding depths in the undisturbed beds both in their finer percentiles (D_5, D_{10}) or in the percentage of very fine sand and silt (% $<$ 0.074 mm). Differences between the artificial redds and the undisturbed bed were less than those between depth zones.

Downstream changes in particle sizes are also small compared to the differences between depths zones at a station. There is little systematic variation in the sizes of the descriptive percentiles of the weight distribution. This holds equally true for the finer (D_{10} or D_{16}) middle, (D_{50}) and coarser (D_{84} or D_{90}) portions of the gravel and cobble population. One important exception is that the silt and fine sand proportion of the overall bed composition increases sharply through the lower half of the river. Figure 6.4 traces this increase by mean size of each age and depth class from the De Rue site, above Willow Creek, to the Fletcher, Powers, and Below Powers sites, affected by runoff from

Willow, Pataha, and Smith Hollow Creeks. The drainage area of the Tucannon River increases by a factor of three over this distance, from about 175 square miles at the De Rue Ranch to about 520 square miles below Powers Road. Figure 6.4 also shows the absence of a comparable trend in the coarser proportion of the bed.

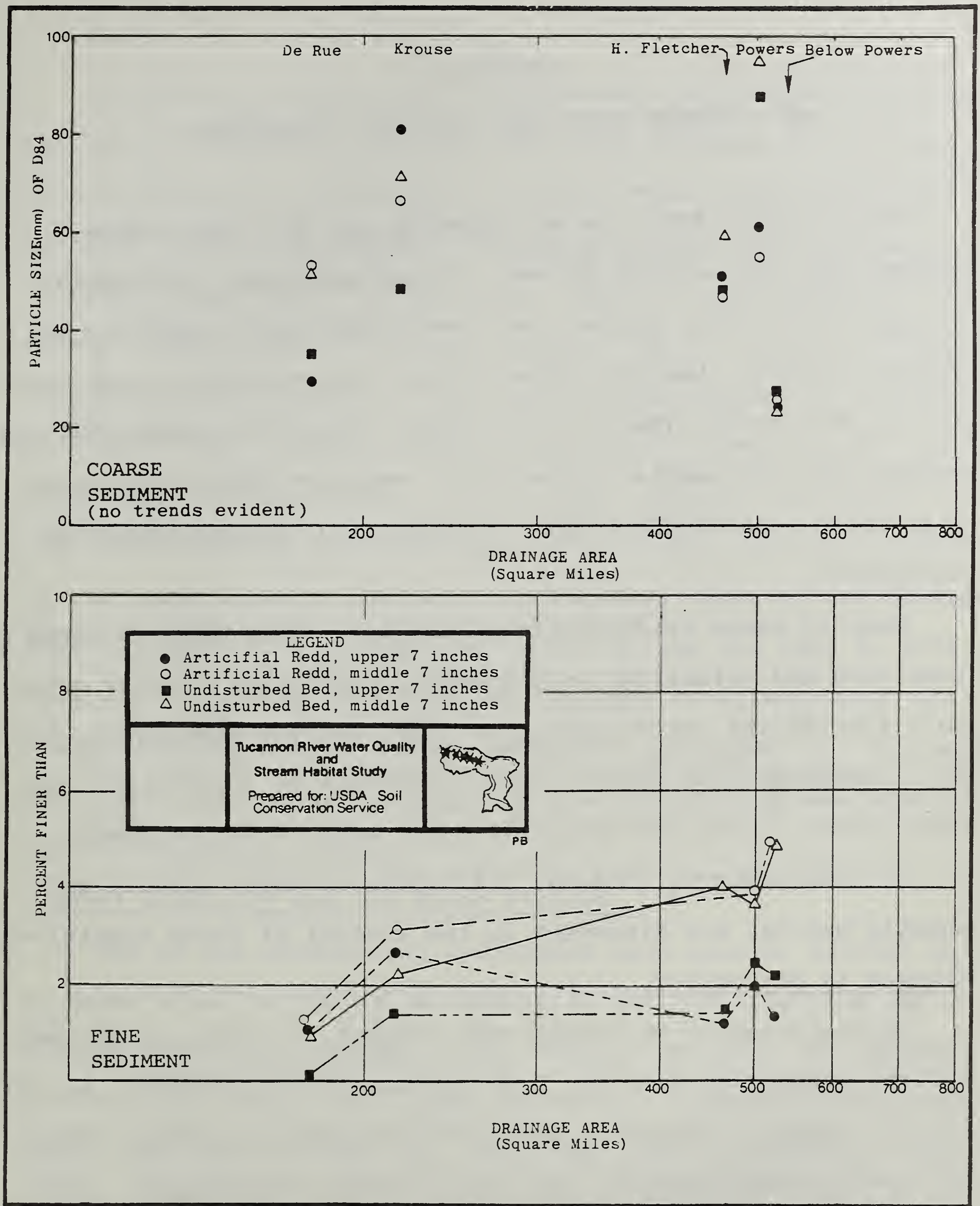

Figure 6.4. Downstream Variation in Coarse and Fine Components of Bulk-Bed Material, Tucannon River, Spring 1981. Downstream increase evident for fine material, but not for coarse.

CHAPTER 7

THE TUCANNON RIVER AND LAND-USE INFLUENCES

The Tucannon River is an adjusting and evolving stream. During the past several decades, it has undergone fundamental changes in the flow regime, bed conditions, water quality, and habitat values. Many of these changes are related to land uses in the watershed. There is no evident reason to assume that the channel and its habitat values have completed their adjustment; and further, the possibilities of additional changes should be recognized.

Many of these transformations are best understood in terms of some rare and unfamiliar environmental conditions. These occur to a significant extent throughout southeastern Washington, and to an important but lesser degree elsewhere in the Palouse and other parts of the dryland small-grain belt of the Northwest.

In this chapter, land-use influences on water quality and aquatic habitat are discussed in the context of these conditions.

Changes in Streamflow.

In the Tucannon watershed many changes in water quality and habitat value have resulted from increased storm runoff. As one result, sediment transport, especially movement of coarse gravel- and cobble-sized material, has been sharply accelerated. Loss of bed and bank stability is very closely related, as is the transition from a predominantly-meandering to predominantly-braided pattern.

A principal consequence of increased storm runoff has been the altered channel geometry of the major streams in the basin. These adjustments--deepening of Pataha Creek, widening of the Tucannon River--are probably the most important indications of increased magnitude of flood peaks. Most of the changes in the Pataha channel seem to have occurred in the first 30 to 50 years following establishment of the agricultural economy in the region. The form of the Tucannon River below Willow Creek is still undergoing long-term adjustment; it is clear, however, that most channel changes in the lower part of the river clearly pre-date the extreme floods of the past two decades. Most of the changes observed above Willow Creek took place during the 1964 to 1978 interval. This includes both the "Marengo to Brines Road" and "Tumalum to Donohue's" reaches described in Chapter 2. Virtually all significant channel changes in the latter reach are associated with this 14-year period.

Channel Stability and the River Pattern.

One of the predominant influences upon aquatic habitat in the Tucannon River is the set of hydraulic and bed stability conditions related to changes in the channel pattern. The stream is swifter than before, and lacks significant pockets of low velocities. The bed and banks are less stable than previously, and the stream is warmer in late-summer months. Hydraulic and geomorphic factors contributing to these changes (and affected by them) are discussed in this section.

The form, pattern, and configuration of natural channels adjust to changes in their hydrologic regimen. We believe that the present condition of the Tucannon River is an adjustment primarily to changes in three of the channel-governing variables:

1. Streamflow: Increases in the magnitude and duration of channel-forming peak flows
2. Width: Increases in width made possible by diminished bank stability due to loss of riparian woodland
3. Coarse sediment load: Significantly more coarse load was introduced, primarily from the banks.

A summary of changes in variables affecting channel form in variables affecting channel form in the Tucannon River is presented in Table 7.1. The table includes our interpretation of which variables affected by land use have imposed change on the channel, which ones adjusted in response to these changes, and which ones were constrained from significant adjustment due to the specific geomorphic conditions prevalent in the area.

These changes in the river, we believe, are both a response to the extreme 1964 and 1965 floods and to adjustment of the channel to an altered runoff and sediment regimes related to land-use practices. From available evidence, it is not apparent which of the two has been more influential. Clearly the greatest effects of the floods have been in the middle and upper reaches of the river, while most changes below Willow Creek or Marengo pre-date these events.

Table 7.1. Channel-Form Adjustment to Flood and Land-Use Influences, Tucannon River

Variable	Vehicle	Flood or Land-Use Influence
I. Imposed (Independent)Variables		
Streamflow	Increased runoff, especially magnitude and duration of peak flows	Increased rates of runoff particularly from cultivated areas; increased drainage density.
Width	Decreased bank stability; accelerated by bar formation during braiding.	Loss of riparian woodland; diminished bank resitance and stability
Coarse sediment Load	Introduced mainly from banks of river.	Induced by increased runoff and bank collapse; induces additional bank collapse
Fine sediment load[a/]	Increased delivery of suspendible sediment	Agricultural practices and other land uses.
II. Constraining Variables		
Depth	Wide, flat valley floor precluded adjustment by depth.	Loss of riparian woodland increases frequency and severity of overbank flows.
Roughness	Lack of significant coarsest material input from banks	Diminished vegetative roughness due to loss of riparian woodland
III. Adjusting (Dependent) Variables		
Velocity	Higher velocities at peak flows; Bed mobility allows greater uniformity of velocity distribution	Miscellaneous
Slope	Braiding, plus some natural cutoffs of meanders	Diminished bank stability Channelization

a/ An independent variable, but one which has probably had minor direct effect on channel form.

The changes presented in Table 7.1 are considered at greater length later in this section, preceded by background discussions of braiding as means of channel adjustment, and of the at-a-station hydraulic geometry, with emphasis on the significance of high velocities occurring in the river.

Braiding. Braiding is the formation of two or more alluvial channels separated by one or more islands or major bars. In common use, the term is restricted to stream reaches in which individual channels and islands often shift while the pattern of almond-shaped islands and channels which divide and rejoin at small angles is conserved. Braiding is one form of adjustment to factors which locally control channel form; it is distinct from a meandering pattern compared to undivided channels with similar flows, braided reaches are generally steeper, wider, and shallower. Streams not uncommonly exhibit both types of channel patterns, although not at the same location.

Changes shown to be associated with an increase in the degree of braiding include a decrease in bank stability, an increase in coarse sediment load (Schumm, 1969), an increase in the magnitude and/or duration of peak flows (e.g. Williams, 1978), an increasing caliber of coarse sediment, and steeper gradients (Leopold and Maddock, 1953). Streams which have become increasingly braided are also often aggrading, but this is by no means always the case.

At-a-Station Hydraulic Geometry. The shape of a channel results from a complex interaction among factors related to its streamflow and sediment load. As streamflow fluctuates, the basic hydraulic characteristics of the channel at a given station may be expressed as a series of simple power functions:

$$\text{Width} = a(\text{Streamflow})^{b}$$

$$\text{Depth} = c(\text{Streamflow})^{f}$$

$$\text{Velocity} = k(\text{Streamflow})^{m}$$

These relations may be developed from measurements of discharge made in a systematic manner, as described in Chapters 3 and 6. The values of the exponents are descriptive of the channel adjustments resulting from changes in streamflow.

An analysis of this sort was made for each of the six gaging stations in the Tucannon watershed. Figure 7.1 is a summary of this analysis for the wading section at the Krouse Ranch gage on the Tucannon River. The values of the exponents indicates that during WY1980 about 9 percent of any increase in flow is accommodated by increasing flow depth, and about 56 percent by more rapid flow.

Use of hydraulic geometry for analysis of channel adjustment in southeastern Washington has three important benefits:

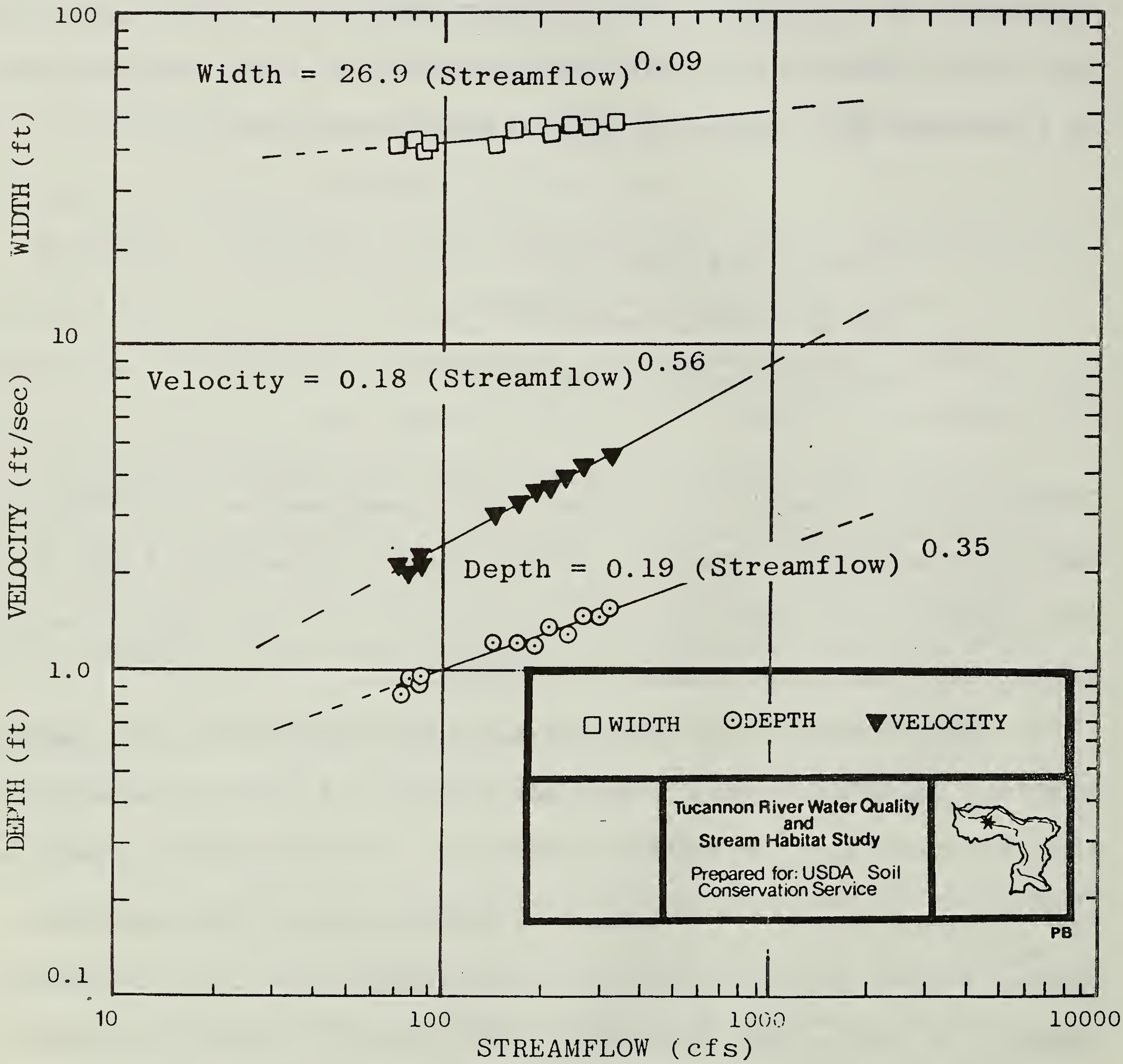

Figure 7.1. At-A-Station Hydraulic Geometry, Tucannon River at Krouse Ranch, Wading Section. Width, depth, and velocity increase exponentially with discharge. Relations may be reasonably extrapolated to 2000 cfs or more based on the trapezoidal, channelized stream section.

1. It enables comparison of different types of streams, such as those within the Blue Mountain (e.g., East Fork Touchet River) and those heading in the loessial hills (e.g. Meadow Creek). The basis of comparison becomes the response of the channel to discharge increments at moderate and high flows. The various stream types are too different to allow use of conventional analyses based on absolute values, such as mean annual runoff or channel width.
2. Effects of altered runoff regimes, due to changes in land use or land treatment, on channel form and stability may be predicted, once these changes are better known.
3. Consequences and causes of the unusually large rate of increase in velocity with discharge may be described and generalized to other locations in the study area.

Mean at-a-station hydraulic geometries in the Tucannon watershed are compared with those of other southeastern Washington streams and of other areas in the Northwest and elsewhere in the country in Table 7.2. The Tucannon streams have configurations which accommodate increases in streamflow virtually identically to other southeastern Washington streams. Very similar at-a-station adjustments occur in the upper Salmon River basin,

Table 7.2. At-a-Station Hydraulic Geometries[a/]

	Exponent of Hydraulic Geometry		
	b	f	m
Tucannon River and Pataha Creek[b/]	.14	.38	.49
Other S.E. Washington Streams	.14	.38	.48
Upper Salmon River, Idaho[c/]	.14	.40	.48
Kaniksu National Forest, Idaho[d/]	.09	.43	.48
Upper Green River Basin, Wyoming[e/]	.16	.38	.44
Midwestern United States[f/]	.26	.40	.34
Ephemeral Streams of the Semi-Arid Southwest[f/]	.29	.36	.34

a/ Hydraulic geometries define variability in some of the flow-related factors which affect the shape of natural stream channels. These often vary as simple power functions:

$$\text{Width} = a(\text{Streamflow})^b$$
$$\text{Depth} = c(\text{Streamflow})^f$$
$$\text{Velocity} = k(\text{Streamflow})^m$$

Where a, c, k are coefficients and b, f, m are exponents, both determined empirically.

b/ Excludes the Pomeroy gage, where Pataha Creek flows through a narrow concrete-lined flume.

c/ Emmett, 1975

d/ Rosgen, Hecht, Kasun, 1977

e/ Dunne and Leopold, 1978

f/ Leopold and Maddock, 1953

upstream of Challis, Idaho. This watershed is similar to the Tucannon River in that it is underlain primarily by volcanic rocks, with much of the remainder of basin being developed in lithologies (such as argillites and limestones) which weather to angular, sand-deficient debris similar to the decomposition products of the Columbia River Basalts. The upper Salmon area differs from the Tucannon basin in many other respects, of which two are especially noteworthy. First, peak runoff is almost entirely in the form of snowmelt, although channel forming floods are often the result of rain-on-snow events. Second, the streams of the upper Salmon basin transport much lower suspended sediment loads than do the non-montane channels of the Tucannon drainage net. Also broadly similar are the areal averages for the former Kaniksu National Forest (near Sandpoint, Idaho), a largely-granitic, partly-glaciated environment with both rainfall and snowmelt runoff crests, and the snowmelt streams of the upper Green River basin in Wyoming. In both of these areas, the rate of increase of velocity relative to that of depth (ratio of m to f) is less than in the volcanic terranes of southeastern Washington and central Idaho. All of these regions are substantially different from the semi-arid Southwest or the midwestern states, the two regions which serve as the source of most of the bank stability and erosion control or land treatment literature.

Peak Streamflows. Peak flows in the Tucannon River are probably larger and occur more frequently than in the distant

past. Rates of runoff during major storms, especially from cultivated lands, have increased throughout the basin. Additionally, and perhaps more significantly, runoff is delivered more rapidly to the main streams through a much denser drainage net. Channels have developed in virtually every depression in the landscape, which in most cases were grassy swales a century ago. Rills and gullies on the slopes are a headward extension of the drainage net, and speed the rate at which runoff reaches the streams. The overall effect is an increase in the incidence and the magnitude of significant, channel-forming flows.

The extent to which these have changed is not known, but is probably substantial. From Whitman County, there are eyewitness reports that channels were little affected until the second or third decade of this century. Boucher (1970) cites studies by Victor in the early 1930's and Kaiser's long-term observations. These established that there was little sedimentation (and presumably channel adjustment) during the floods of 1894 and 1910, although these were probably the largest of record until the mid-1960's. Yet, by the mid-1930's channels had widened, and were undergoing rapid headward erosion. It is also possible that climatic cycles since World War II may also be affecting the magnitude and frequency of peak flows to some degree.

Width. Larger woody vegetation--and particularly the dense riparian woodland--stabilizes the Tucannon River banks. The banks are composed of material which appears identical to the

bed sediments. Without the framework of interlocking roots, the banks are susceptible to undercutting and collapse.

The proportion of wooded banks decreased radically during the period of 1937 to 1978. For the four reaches considered in Chapter 2, wooded bank lengths in 1978 were only 12 to 48 percent of those in 1937. The diminished bank stability was only partially offset by construction of revetments and causeways. Loss of bank stability, in itself, appears to have been a major factor encouraging development of a wider, more braided channel pattern. Relative bank stability is perhaps the most important factor governing the proportionate widths (width-to-depth ratios) of streams. particularly for braided channels (Schumm, 1969, and other studies). Leopold and Miller (1953, p. 63-4) noted the importance of riparian vegetation in determining channel shape:

> "The width of a river is subject to constant readjustment if the banks are not well stabilized by vegetation. The magnitude of the readjustment depends on the nature of the banks and the amount and type of vegetation they support. In the eastern United States river banks generally tend to be composed of fine-grained material having considerable cohesiveness, and large trees typically grow out from the bank and lean over the stream. Their roots are powerful binding agents, and under these conditions width adjustments are small and slow. Only the large floods are capable of tearing out the banks. In the semiarid West width adjustments appear to be greater owing to generally more friable materials making up the banks and to less dense vegetation."

Width adjustment in the Tucannon River, we believe, is a response primarily to diminished bank stability induced by the floods and by clearing of the riparian woodland for other land

uses. Larger and more frequent flood peaks probably also have contributed to a wider channel, as have other hydraulic and morphologic influences. It may be that the 10 to 12 years following the big floods were a period of unusually frequent high, channel-shaping flows. If so, some re-colonization and re-stabilization of the banks by riparian trees may now be taking place, likely leading to diminished widths, braiding, and bed instability.

Coarse Sediment Loads. Bedload transport rates in the Tucannon River are low, both relatively and absolutely. This is largely due to the soil and rock types, and to other geomorphic and land-use factors. Significant widening of the high-flow channels during the past 40 years or more, by the process of bank erosion, introduced very large amounts of coarse debris into the channel. Upstream of Willow Creek, widening of the channel during the 1964-1978 period introduced coarse material equivalent to the amount of average annual bedload transport for a period of several decades. Much or most of this material probably remains in storage in the bed, one important reason for the similarity of bed and bank deposits.

Braiding, width, and coarse load constitute a positive feedback system in the Tucannon River. An increase in the degree or extent of braiding is a response to greater coarse loads, and is associated with an increase in width. With diminished bank stability, this generates additional coarse load. The main parameter limiting widening of the channel to the full width of the valley is the lack of sufficient peak streamflow.

Future increments in peak flows, if any, are likely to lead to more braiding, greater widths, and increased bank erosion. Conversely control of runoff can result in stabler and more vegetated banks, and a narrower, more meandering channel.

At the onset of this study, we put forth the hypothesis that coarse debris introduced from the many tributaries and nameless valley-side arroyos might have been responsible for the changes in channel form. Careful interpretation of the aerial photographs indicates that these channels were fully developed by the late-1930's, if not earlier. Little or no perceptible increase in the widths or depths of even the larger unnamed streams could be distinguished during the 1937 to 1978 period.* Most of the limited extent braiding affecting the river in 1937 appeared to occur downstream of the larger arroyo or tributary confluences. This suggests that adjustments to greater or coarser sediment loads at these locations had been taking place. These involved the same general accommodative processes observed during the subsequent 40 years. It is clear that the early hypothesis should be rejected in light of the evidence that the additional increment of coarse sediment originated as Tucannon River alluvium.

<u>Fine Sediment Loads.</u> The relationships between land use and accelerated soil loss and rates of suspended sediment transport in the streams of southeastern Washington have been established by previous workers (Kaiser, unpubl.; Boucher, 1970; USDA, 1978).

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* This observation applies to the Tucannon River below Tumalum Creek and to Pataha Creek below Sweeney Gulch; development of the small channels upstream of these points could not be distinguished from the aerial photography.

Suspended-sediment loads are presently much higher than a century ago. Unlike the coarser sediment, virtually all of the suspended sediment originates on uplands and slopes far removed from the channel. The load of fine material is largely independent of channel form. We believe that its effect on adjustment of the Tucannon River channel is small relative to those of streamflow, width, and coarse sediment load.

Depth. Greater runoff cannot be accommodated by significant increases in depth of flow in the Tucannon River. Under natural conditions, the river has a wide flood plain only several feet higher than the bed. Overbank flow, under very different hydraulic conditions, results when flows exceed the level of the banks. The wide flood plain is unusual; most streams in the western states are constricted by terraces composed of older alluvial seimdents. Adjustment of depth is generally restricted to the channelzed reaches of the Tucannon River.

Two other conditions appear to have further constrained adjustment of depth. First, loss of riparian woodland increased the frequency of overbank flow; the opportunity and capacity to cut new channels increased accordingly. Second, the heavy influx of coarse sediment from the eroding banks seems to have induced buildup (aggradation) of the bed. We have been unable to unequivocally establish from primary data that the channel has aggraded. This is, however, the impression of so many long-term residents of the valley that its likelihood may be at least postulated. There is clearly no evidence for any downcutting of

the bed. An aggrading bed may be expected for braided channels adjusting to greater floodflows and increased coarse load (Schumm, 1969; Williams, 1978; Leopold and Maddock, 1953).

Roughness. Unlike most streams subjected to increased runoff and sediment loads, roughness of the Tucannon River bed is not amenable to significant increases. Lacking eroding tributaries or extensive cutbanks, virtually no debris coarser than material composing the bed and banks is usually introduced. The riparian woodland at one time imparted significant roughness to the channel, either in the form of snags and fallen trees or as a resistive mat of roots and limbs along the bank. Similarly, roughness imparted by dunes, bars, and riffles--so commonly a means of hydraulic adjustment--could not develop due to the lack of sand and fine gravel in the alluvial system.

Velocity. The velocity of flow during storm runoff events shaping the channel probably has increased substantially with the change in channel form. Only part of the increased flows can be accommodated by a wider channel; the remainder must be accounted for by deeper or swifter flows. The dependent character of flow velocity (v) and also of channel slope (S), givern the constraints in depth (d) and roughness (n) may be seen from the familiar Manning equation:*

$$v = \frac{1.5}{n} d^{2/3} \quad S^{1/2}$$

* This is a simplified version, suitable for use in wide streams, of the more rigorous equation:

$$v = \frac{1.486}{n} \left\{\frac{wd}{w+2d}\right\}^{2/3} \quad S^{1/2}$$

The effects discussed in the text would be even more pronounced in the unsimplified form.

If mean depth of flood flow actually decreased slightly (as we believe to be the case), the increase in peak runoff must be accommodated by at least some increase in the velocity of the stream. The more rapid flow must therefore be associated with an increase in channel slope. The main stem of the Tucannon River has been steepened by about 10 to 15 percent due to the channel changes, suggesting that velocities at significant sediment-moving flows are about 4 to 5 percent higher for a given discharge. The effects of high flow velocities on the configuration of the bed, discussed above, therefore affect the bed more often and more severely. High velocities are further discussed in a following section.

Slope. Slopes of the main-stem channels of the Tucannon River have increased,* at least below Tumalum Creek. For the four representative reaches considered in Chapter 2, reduction of channel length ranged from about 6 to 17 percent. The magnitude of this adjustment is large. It should be understood as an accommodation to increased storm runoff and decreased bank stability under conditions precluding any increase in depth or roughness. Seldom are depth and roughness both constrained.

In Chapter 2, we noted that the Tucannon River is steep by comparison to Pataha Creek and some other southeastern Washington streams. The stream's overall slope is probably at least in part

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* The lowermost several miles of stream are an important exception. These fall within the tailwater influence of the Snake River reservoirs, and are aggrading. This process noticeably affects channel pattern, bed-material sizes, and channel morphology up to a point slightly downstream of Powers Road.

relict from uplift of the Blue Mountains. Additionally, downcutting of the Snake River may also have influenced the gradient. With the possible exceptions of Asotin and Alpowa Creeks, the Tucannon River has the most direct course between these two areas of changing level. Braided channels develop more readily in steeper streams (e.g. Leopold and Maddock, 1953).

High Velocities of Flow.

Throughout this study, the occurrence of high velocities even at relatively low flows has been noted in numerous contexts. The rate at which velocity increases with increasing discharge is also large (figure 7.1 and table 7.1). At higher flows, such as those which shape the channel form, velocities in the Tucannon River can be very large for a stream of its size. Some processes which occur in the Tucannon River are those typical of very high relative velocities, and which are generally not encountered in larger alluvial streams. Most of these are related to braiding, and are largely responsible for the lack of pools in the river.

Development of Supercritical Flow. One important example is the transition to supercritical flow, which is not uncommon in the river. Supercritical (or "shooting") flow develops in most fluids at Froude numbers* in excess of about 1.0, a threshold which

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* Froude number is a dimensionless index based on the ratio of inertial to gravity forces. In an open channel, this becomes

$$F_r = \frac{v}{(gd)^{1/2}}$$

where F_r, the Froude number, is the ratio of mean velocity to the square root of the product of the gravitational constant, g (32.2 ft/sec^2), depth, d. Supercritical flows are shallower and more rapid for a given discharge than subcritical flows. They exert greater effective shear on the bed, and are generally capable of detaching material of larger size than the equivalent subcritial flow.

seldom is exceeded in alluvial seetings. The hydraulic geometry for this gage (figure 7.1) indicates that a mean channel Froude numbers above a value of 1.0 develop at flows greater than 1000 cfs. At 1000 cfs, the mean velocity of flow is about 8.6 feet per second, with a mean depth of about 2.3 feet. This analysis presumes that the hydraulic geometry observed at flows of 50 to 350 cfs may be extrapolated to discharges of 1000 cfs; we consider this to be a reasonable approximation for the purposes of this analysis.

What effects is supercritical flow likely to have on the bed? Greater rates of scour and fill may be expected. The higher velocities of the supercritical condition have the capacity to transport bedload more rapidly, and are competent to move larger bed cobbles. Similarly, the flow exerts greater shear on the banks, especially on the coarser or more cohesive material commonly found at the base of the banks. Simultaneously, deposition is also accelerated, in part because the flow is prone to become subcritical whenever a locally deeper or quieter portion of the bed is encountered. Pools and the eddies behind larger roughness elements such as boulders or fallen trees are rapidly filled as the stream is adjusted to maintain a high and uniform velocity.

A transition to supercritical flow at the Krouse Ranch reach may be expected to occur at least two out of three years, based on the expected frequency of flows exceeding 1000 cfs. In actuality, both large-scale laboratory (e.g., Herbich and Schulits, 1964)

and field studies (e.g. Judd, 1963) indicate that a transitional condition develops over at least portions of the channel in cobble-bedded streams beginning at Froude numbers of about 0.75 to 0.80, with properties similar to fully-supercritical flow. In the Krouse Ranch reach, this occurs at discharges exceeding 650 cfs, a flow which occurs almost every year, commonly during periods when eggs are likely to be in the gravels.

The high velocities also contribute to burial or loss of larger roughness elements. Scour around boulders causes them to settle into the bed during the persistent high-velocity flows of rainfall or snowmelt runoff. Snags and fallen trees are more easily washed from the active channel and deposited high on bars, where they cannot affect rearing habitat.

Importance of Extreme Events. The high velocity and large rate of increase in velocity with discharge can also shed light on the importance of extreme events in channel form and sediment budgets in southeastern Washington. The rate of velocity increase with discharge (the exponent "m" in the hydraulic geometry) approaches .50 at typical stations in the region. This is among the largest values of the exponent reported in the literature. Similarly, the rate of increase in velocity relative to depth is also very large, a relationship which may be expressed as the ration of "m" to "f" in the hydraulic geometry. The m/f fraction in most channels varies from 0.60 to 1.0. In other words, depth generally increases more rapidly than veloctiy. The reverse is true in southeastern Washington, where the m/f fraction averages about 1.20 to 1.25.

Experience has demonstrated that large values of m/f are associated with unusually rapid increases in sediment load with streamflow.* Whereas in most streams, sediment transport rates generally increase with 1.5 to 2.5 power of streamflow (e.g., Dunne and Leopold, 1978) rates generally increase with the 2.5 to 4.5 power of streamflow in most southeastern Washington streams (figures, 4.2 through 4.5 and 4.8). Transport rates at flood stage are thus 10 times or more larger in this region than at equivalent flows elsewhere in the nation. Thus, events which might occur only every 5 or 10 or more years transport much greater percentages of the total long-term sediment yield in southeastern Washington than might be true of a stream in another region. The more extreme the flood, the greater the disparity.

There are two consequences of this condition which merit mention. First, extreme events are unusually important in the long-term sediment budget of southeastern Washington streams. Sound data collected during these rare runoff events are thus especially informative. No extreme events occurred during WY1980. The observations made by the U.S. Geological Survey staff during the WY1963 and WY1965 events should be considered as particularly helpful in developing sediment budgets. Second, most procedures used to average or normalize sediment transport data to longer periods of record may not be effective in the Tucannon basin.

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* As with many other facets of channel adjustment, high m/f statistics both affect and are a result of sediment transport-to-streamflow relations. See Leopold and Maddock (1953) or Leopold, Wolman, and Miller (1964) for a discussion.

Storms with recurrences of less than 1.5 to 2.0 years transport most sediment in most streams. This does not appear to be true for the southeastern Washington channels. Different approaches, and a longer period of data collection, will be needed to establish long-term yields, even neglecting factors other than the importance of extreme events.

Structure and Texture of the Bed.

How do these properties affect the intra-gravel environment critical to salmonid spawning, egg survival, and alevin emergence? Most conventional analyses of the suitability of the bed environment rest on at least three assumptions, generally unvoiced:

1. The redd is sufficiently uniform throughout its depth so that the bed environment may be described by a one- (or occasionally two-) layer system.
2. The overwhelming influence of the bed on spawning success and survival of the young is that it be able to pass sufficient flow to keep the redd properly oxygenated and free of metabolic wastes.
3. The bed is composed of material with sizes distributed log-normally, or in a manner sufficiently close to log-normal so that statistical procedures based on the normal distribution may be used after minor adjustment. A correlate assumption is that the roles of the various debris sizes may be expressed as a function of one property--weight proportion of the distribution.

Applicability of the first two assumptions is discussed in

this section. In the following section, the third premise is considered.

Horizonation of the Redd and Adjacent Bed. In the reconnaissance analysis of the bed composition (Chapter 6), we tentatively postulated a two-layer model of the bed. This included a relatively thin, lightly-"armored" surface horizon, and deeper "bulk-bed" material which, while not necessarily uniform with depth, is sufficiently similar to be described with a single vertically-integrated sample. How well does this model of the bed hold up in light of the data obtained in freeze-coring?

The answer, we believe, is somewhere between moderately and poorly. The model probably applies to at least some significant portions of the bed in the central and upper portions of the river. Below Willow Creek, the number and contrasting characteristics occur at too fine a scale for one - or two-layer models to be acceptable. Median thicknesses of individual sedimentologic horizons vary from about 4 to 6 inches, small relative to the depth of the redd. Another important complication is the sometimes extreme differences in particle sizes, fabric, or degree of induration. Additionally, there is convincing evidence for periodic scour (and/or replacement) of the bed-surface layer.

In all probability, the vertical variability of the Tucannon River bed is simply characteristic of braided channels. These tend to be relatively homogeneous in the downstream or cross-channel direction, but are inherently variable with depth (e.g. Williams

and Rust, 1969). Additionally, the period during which the artificial redds were monitored was one of occasional moderately-high flows, sufficient to scour or deposit several inches of material but not large enough to extensively re-work the bed. Depositional sequences in non-braided channels are typically thicker; vertical variation in particle size ordinarily is both relatively less and more systematic.

An important factor contributing to fine-scale horizonation in the bed and redds is the gradual development of indurated zones. Although finer material infiltrates into bed sediments in many streams, it seldom occurs as markedly, widely, and rapidly as observed in the Tucannon River, and presumably in other streams draining basins developed in volcanic and loessial materials. Induration adds to the vertical complexity of the bed and redd system. It creates physically-distinct horizons largely independent of the depositional stratigraphy of the bed. Additionally, induration may induce radical differences in physical properties of adjacent horizons. Effective permeabilities in adjacent horizons may differ by two orders of magnitude, or more in some cases. This degree of variability within the 12- or 16-inch section of the bed used for egg incubation is both unusual and unfamiliar.

For salmonids, the stream bed provides an environment in which eggs may incubate within a relatively narrow range of flows, while remaining protected from scour, buffeting, or predation. The bed setting also affords a buffer against abrupt changes in temperature or water quality. Emergent alevins also must pass through the bed.

In most stream bed environments, inadequate bed permeability is the physical factor most likely to limit egg or alevin survival. Other influences of the bed are generally neglected. This may not necessarily be a valid assumption in streams such as the Tucannon River, with marked horizonation and bimodal sizes of bed material. Scour might possibly be another major cause of mortality; about half of the artificial redds or other instrumentation installed to monitor the intra-gravel environment during the course of this study were lost to scour. It is also possible that bed induration may inhibit alevin emergence.

Particle-Size Distribution of Bed Material. Another of the major unfamiliar conditions prevalent throughout the Tucannon channels is the size distribution of the bed material. There are at least two, anomalous aspects the bed-material size distribution:

1. The bed is composed of two distinct populations--cobble and gravel on the one hand, silt, clay, and very fine sand on the other. The two populations have different primary sources, are mobilized by different flows, are transported and deposited by different processes at different times. The particle-size distribution of bed material is thus markedly bimodal.
2. Sand and fine gravel are strikingly lacking in the Tucannon basin. This is particularly true for material ranging from fine-to-medium sand (0.50 mm.) to fine-to-medium gravel (8 mm). Deficiency of sand and fine gravel affects the channel and bed in many subtle ways. One example is

that much finely-divided organic matter infiltrates into the bed interstices in the Tucannon watershed and presumably in other streams of southeastern Washington. Most of this material would be retained at or near the bed surface in environments with sufficient sand to provide some degree of filtration.

Given these unusual or unfamiliar conditions, how can the effect of fine sediment on the redd be best determined? Two approaches to this question are in widespread use. The first involves determining the proportion of material below an index size. Intra-gravel environments with high percentage (by weight) of material finer than this index size are considered poor. The relation between this percentage and egg or alevin survival is empirically determined, usually under laboratory conditions and occasionally in the field. This approach effectively is based on the hydrogeologic concept of intrinsic permeability, which relates flow to an index pore diameter assumed to be proportional to a representative grain size. An alternative approach is describing the properties of the bed based on the sorting or statistical dispersion of particle sizes. Well-sorted bed material is commonly more porous and significantly more permeable than poorly-sorted sediments of similar mean or median size. The latter approach has significant advantages, and is coming into wider use. Recent examples include Platts and others, 1979; and Tappel and Bjornn, 1980. Both approaches are based on distribution of sizes by weight. Both also depend on computations based in large part on the sizes of material from one to two standard deviations finer than the mean size. Commonly, the index sizes or statistical descriptors

emphasize sizes rougly equivalent to the size of material for which 10 or 16 percent by weight is finer (D_{10} or D_{16} in the notation used for this report).

After much analysis, we believe that neither approach can be applied to the Tucannon River without additional basic research. Four conditions affecting the bed specific to the southeastern Washington area need to be considered.

1. Gravels and silts have different physical properties that should be recognized. For example, the role of silts and clays in the bed environment is not readily expressed as a weight percentage. Deposits composed of these materials are much less dense than beds of gravels and cobbles. Water-laid deposits of silt with some fine sand typically have specific dry weights of 30 to 40 pounds per cubic foot. Gravel and cobble alluvium in the Tucannon River might have unsaturated specific weights of 110 to 120 pounds per cubic foot, based on weight and volume data collected by SCS staff at the De Rue site. Because the interstitial material is so light relative to the gravels, its effect on bed permeability is markedly under-estimated when the silt content is expressed as a weight percent. As an example, the porosity of coarse gravel alluvium is generally about 20 percent. Reduction of porosity to 5 percent by infilling with silt might be expected to reduce permeabilities by at least a factor of 10. The additional 15 percent by volume of silt with fine sand would constitute roughly 4 percent of bed material

by weight, using the specific weights discussed above.

2. The proportion of finer material in the bed of the Tucannon River probably changes, often gradually, with time. Most studies of egg survival are based on bed-material size distributions which do not appreciably change over time.
3. Horizonation in the bed of the Tucannon River is developed to an unusual extent (previous section). Use of particle-size distributions from several horizons to characterize the water-bearing properties of the bed may or may not be effective. It is likely that separate consideration of extremely different horizons within a redd, when encountered, will help control interpretive problems posed by this condition.
4. The fine sediment not only inhibits flow through the bed, but it also exerts a substantial oxygen demand. Beyond a certain critical degree of infilling, dissolved oxygen levels in the bed probably decline rapidly as the effects of sediment-generated oxygen demand are added to those of diminished flow rates. In spring months, there may also be a simultaneous increase in oxygen demand related to rapidly-rising water temperatures.

We now believe that new approaches to interpreting flow properties within the bed will prove fruitful. Rather than adapting indices suitable for more familiar sizes and distributions, approaches based on volume distribution of the silts and/or the rate of accumulation within the bed might be effective. Data collected in the coarse of this study are not amenable to developing an analysis

based on volume, but this could be readily accomplished using similar equipment.

Role of Finely-Divided Organic Matter. The role of the finely-divided grasses and crop residues merits additional comment. These compose a visibly-significant part of the bed throughout the portions of the basin below the Blue Mountain front. They are especially prevalent below Willow and Pataha Creeks.

The fine organic matter is transported both in suspension and as bedload. Much, and often most, of the bedload samples collected at moderately-low flows (less than 200 to 250 cfs in the Tucannon River) consisted of accretions of silt/clay with an organic binder. These were informally labelled "hayballs" in the course of our studies. By far, most of the fine organic matter, however, appears to be transported in suspension.

Relatively large components of organic material in either the transported sediment or in the bed environment are not familiar conditions, at least within the range of Pacific Coast salmonids. Their effect on bed permeability and intragravel dissolved oxygen levels do not appear to be known. Using analyses by Dr. Michael Falter of intra-gravel waters collected by Paul Rogers and Ivan Lines, Stacy Li estimated by multiple regression that organic matter is (with percent total fine sediment) one of the two major factors influencing the dissolved oxygen levels in the artificial redds. The mechanisms by which this occurs have not been determined in the course of this study. Presumably, the finely-divided

organic matter acts to reduce bed permeability, perhaps acting as a fabric or binder for the intra-gravel silts. It should be noted that the organics are less dense than the inorganic fine sediments, and they often are in expanded form when wet. Their physical role in the bed may be under-stated when their content is expressed on a dry-weight basis, much in the same way as for the fine inorganic component of the bed relative to the larger gravels and cobbles.

We believe that the oxygen demand exerted by decomposition of the fine organics may also be significant, particularly when the intra-gravel water is warm. There is no direct evidence supporting or refuting this hypothesis. In our opinion, additional study of this question is warranted. If it proves to be substantial, considerable improvement in spawning success might be obtained by relatively simple conservation measures reducing the delivery of organic matter to the stream.

Land-Use Influences on Bed Structure and Texture. Land-use practices influence both the development of these conditions and their effects on fish. The principal influence, we believe, is the complex set of factors which have caused increased braiding of the river--notably increased runoff and diminished bank stability. The transport rates of suspended sediment, clearly related to land use, are perhaps the primary factor affecting the rate at which infilling by fine sediment developes. The role of organic matter in the intra-gravel environment remains unclear; land use, agricultural practices, and land treatment all affect the amount available for delivery to the channel net. The relationships between

land use and bed conditions are much more complex than envisoned in the authorization and planning of this study. Some of the relationships are unusual or unfamiliar. In other cases, the soil and geomorphic conditions in the Tucannon basin are forcing recognition of new sets of linkages between land use and bed conditions are much more complex than envisioned in the authorization and planning of this study.

CHAPTER 8

SUMMARY

The conditions and findings described in this report are summarized in this chapter, together with those discussed in the companion report of D. W. Kelley and Associates. Many of the observations presented in these studies were made by staff members of the Soil Conservation Service and the University of Idaho, and also by local residents and other field scientists participating in the USDA Cooperative River Basin Study. Re sponsibility for these conclusions, however, rests with the two consulting firms.

Evolving Channel Conditions.

Changes in Channel Form. There have been profound changes in the channel and riparian zone during the past 40 or 50 years. Using aerial photos taken in 1937 and 1978, we established that:

1. The river has changed from a predominantly meandering pattern to one that is primarily braided.
2. The channel is presently much steeper and shorter (6 to 17 percent, depending on the reach).
3. Woodland areas on the valley floor have been sharply reduced (by 34 to 49 percent) by the major floods, by subsequent bank erosion, and by encroachment of other land uses.
4. Wooded banks, which shade the stream and stabilize the channel, have been reduced by 52 to 88 percent.

Below the mouth of Pataha Creek, these changes developed continually

and consistently over the 41-year period. This conclusion is based on our interpretation of other aerial photographs taken in the summer of 1954 and 1964. Most changes above Pataha Creek occurred between 1964 and 1978, and are probably related to the floods of December 1964 and January 1965, plus subsequent major events. Some braiding and evidence of diminishing bank stability could be seen in all reaches on the 1937 photos.

Consequences of Channel-Form Changes. The channel is now wider and shallower, with swifter and warmer flows. The bed appears to become mobile at surprisingly low flows (often about 250 to 300 cfs), which occur several times a year. Snags, boulders, and fallen trees are much less abundant. Long pools and beaver ponds have disappeared or been reduced to a small fraction of their former volume. These changes are all thought to have adversely affected spawning and rearing habitat values.

Causes of Channel-Form Change. After considerable analysis, we concluded that the channel form is adjusting to increased runoff, much-diminished bank stability and the related major increase in coarse sediment loads. Larger and/or more frequent peak flows have been accommodated by increases in width and velocity. Depths at high flows have remained relatively shallow, due in part to the influx of coarse debris from the banks. Unlike most streams adjusting to greater or more frequent peak flows, the hydraulic roughness of the Tucannon River has apparently decreased as riparian woodlands were lost and as the bed filled with gravels from the banks. Constrained by diminishing depths and roughnesses, increases

in velocity of necessity were associated with a steepened slope and a related increase in the extent of braiding.

Relation of Land Use to Channel-Form Changes. Most uses of the land in the Tucannon basin generate more (and more rapid) runoff than was true a century ago, although the extent of this increase has not yet been quantified. Further, its effects are inseparable and indistinguishable from those of the severe floods which have affected the basin since 1963 with perhaps abnormal frequency. Any substantial increase in the relative magnitude or duration of flood flows will serve to maintain or aggravate present condition of the channel, given the diminished stability of the banks.

Between 1937 and 1964, the area of riparian woodland upstream of Pataha Creek was reduced by about one-third, primarily by conversion to fields, farmsteads, and other uses. We believe this contributed to the extent of bank erosion and changes of channel course which occurred during the winter of 1964-1965.

Conditions and Monitoring Results, Water Year 1980.

Streamflow. Runoff from the Tucannon watershed during WY1980 averaged 158 cfs, or about 11 percent below the mean for the previous years. Rainfall in Pomeroy and Dayton was slightly above average for the period of record, while the snowpack in the Blue Mountains was slightly below normal. Maximum snowmelt occurred two to three weeks earlier than usual.

Significant Events Affecting Runoff or Sediment Production. Unusual and significant events during water year 1980 affecting runoff or sediment yields included:

1. A large mud avalanche in the Bear Creek sub-watershed near the head of the river.
2. Heavy snow accumulation in early January, followed by warm rains; at most stations, nearly half of the annual sediment yield was measured during the four days beginning January 12.
3. Runoff from a major cloudburst on June 16 produced the largest flow peak during the year.

Ash from the eruptions of Mt. St. Helens fell on the northernmost portions of the watershed, notably on May 18, 1980. Maximum accumulations were well under one inch. Its direct effects on sediment yields or aquatic habitat are considered negligible. The amounts of sediment leaving the Tucannon watershed during WY1980 were substantially more than entered the basin in the form of ash.

Suspended Sediment. During the 1980 water year, suspended-sediment yields from the basin were about 146000 tons, as measured near the mouth of the river at Powers Road. Most of the sediment was generated from areas below the Blue Mountain front and upstream of the mouth of Pataha Creek. The smallest sediment yields per unit area were in the Blue Mountains. The greatest sediment yields were from portions of the Pataha watershed downstream of Pomeroy and upstream of Chard Road, which were equivalent to about 1.4 tons per acre.

Bedload Sediment. Yields of bedload material during water year 1980 were much smaller, generally being about 1 percent of

of the suspended sediment transport in the Tucannon River and even less in Pataha Cr. Most of the bedload is composed of material derived from the banks or bed; bank erosion during floods is substantial, and likely to produce much greater transport rates than those observed during 1980. Medium and large gravel sizes predominate, with some cobbles and minor fine gravel and sands. During periods of low bedload transport, most of the samples we gathered consisted of "hayballs," marble- to walnut-sized balls of fine sediment with a binder of organic matter, mainly grass and crop residue.

Water Quality. Levels of nitrates and other major dissolved solids (salts) are well within standards set for public water supplies or agricultural use. Nitrate and salts concentrations are moderately higher in samples drawn from the bed, probably a result of their release into solution from finely-divided organic matter and suspended sediment. We found no indications of harmful effects to aquatic organisms within the Tucannon River.

Water Temperatures. Water temperatures in the middle and lower portions of the Tucannon River become too warm by early or mid-August to support young salmonids in large numbers. High temperatures limit use of the lower 29 or 30 miles of the river, from near Bridge 12, or about midway between Tumalum Creek and Marengo. Late-hatchery steelhead and rainbow trout eggs remaining in the bed below Tumalum Creek may also be threatened by water temperatures. The dominant cause of excessive water temperatures is lack of shade. Daily temperature maxima in the river increased immediately after

the major storms of 1964 and 1965, which widened the channel and destroyed much of the riparian woodland.

The Aquatic Resource.

Fishes. Sixteen species of fish were found in the Tucannon River:

1. Steelhead and resident rainbow trout (*Salmo gairdneri*)
2. Chinook salmon (*Oncorhynchus tschawytscha*)
3. Dolly varden (*Salvelinus malma*)
4. Pacific lampreys (*Entosphenus tridentatus*)
5. Mountain whitefish (*Prosopium williamsoni*)
6. Carp (*Cyprinus carpio*)
7. Chiselmouth (*Arcocheilus alutaceus*)
8. Redside shiner (*Richardsonious balteatus*)
9. Longnose dace (*Rhinichthys cataractae*)
10. Speckled dace (*Rhinichthys osculus*)
11. Northern squawfish (*Ptychocheilus oregonensis*)
12. Bridgelip sucker (*Catostomus columbianus*)
13. Longnose sucker (*Catostomus catostomus*)
14. Smallmouth bass (*Micropterus dolomieui*)
15. Piute sculpin (*Cottus beldingi*)
16. Margined sculpin (*Cottus marginatus*)

Other species reported as occurring in the stream include:

1. Brook trout (*Salvelinus fontinalis*)
2. Pink salmon (*Oncorhynchus gorbuscha*)
3. Channel catfish (*Ictalurus punctatus*)

Additionally, coho salmon (*Oncorhynchus kisutch*) were last seen in

the river in 1955. The total fish biomass was considered to be high, especially in pools. Salmonids constituted 43 percent, with most of the remainder being sculpin and dace.

Most common in August, 1980, were young-of-the-year and yearling steelhead and young-of-the-year chinook. Growth rates of young salmonids in the Tucannon River are rapid by comparison with other Pacific Coast streams. Most salmonids were found upstream of Marengo or Tumalum Creek, where the water is sufficiently cool. An important exception is a small population of fall-run chinook, which evidently use the tailwater environment below Powers Road near the mouth of the river.

<u>Spawning.</u> Dissolved oxygen levels in artificial redds were measured during two winters by ; associates and by Paul Rogers and Ivan Lines, Jr., of the SCS staff. In the upper one-third of the stream, levels of dissolved oxygen in redds are likely to be adequate throughout the period of egg incubation and emergency of the young. Adequate levels are seldom sustained below Pataha Creek. Below the hatchery and above Pataha Creek, conditions apparently vary by year and location. The depressed oxygen levels are caused by diminished permeabilities associated with deposition of fine sediment within the bed interstices, and likely also by the oxygen demand exerted by the large amounts of finely-divided organic matter found with the fine sediment.

<u>Rearing.</u> Kelley and Li assessed rearing habitat along the length of the river using a numeric procedure described in their report. The species and numbers of fish using pools, riffles, and

glides in the upper half of the river were determined by electrofishing, with the results used to calibrate the habitat assessment. If water temperatures were not too warm, the physical habitat in the Tucannon River below Sheep Creek could support about 430,000 chinook salmon to at least the middle of the first summer. Actual populations censused in late-summer 1980 were near 111,000 yearling steelhead and 170,000 chinook, about 40 percent of the potential. The primary constraint is elevated water temperatures in the middle and lower reaches of the river, and probably a lack of suitable spawning habitat below Pataha Creek.

Invertebrate Fauna. Populations of insects and other invertebrate fauna were sampled in June and September 1980 at five locations from Camp Wooten to near the mouth. Total numbers and weights of invertebrates per square foot of Tucannon River bed are similar to, or larger than, those reported for other streams where comparable measurements have been made. The invertebrate fauna was highly diverse at all stations during both sampling periods. Kelley and Li present observations suggesting that water temperatures affect the types and numbers of invertebrates in the Tucannon River to a moderate degree; fine sediment, bed instability, and high velocities also restrict these types and populations, but to an apparently minor extent.

Periphyton. Communities of algae, fungi, bacteria, protozoa, and similar organism growing together on solid substrate were abundant and widespread during the summer of 1980. Densities at five sites from Camp Wooten to near Starbuck were similar. In the

upper reaches of the river, cool enough to be used by fish, about one-sixth to one-third of the insect population depends primarily on periphyton for food supply. We found no evidence to indicate that periphyton densities limit the numbers or kinds of fish in the river.

Nature of the Bed and the Intra-Gravel Environment.

Conditions Specific To Southeastern Washington. The Tucannon River bed is affected by four unusual and unfamiliar conditions:

a. The bed is composed of two distinct particle sizes--coarse (cobbles and gravels) and fine (silt, clay, with some very fine sands). The two are separate populations which have different sources, are mobilized by different flows, and are transported and deposited at different times by distinctly different processes.

b. The channel and watershed of the Tucannon River are both strikingly lacking in sands and fine gravels, particularly material ranging from 0.50 to 8 mm. This deficiency affects the bed environment in many subtle ways.

c. Very hard and dense horizons form by fine material infiltrating into the interstices within the bed. These indurated horizons apparently form over periods of several days to several months, and can extend over distances of hundreds of feet along and across the channel.

d. The fine infiltrating sediment is rich in organic matter, primarily finely-divided grasses and crop residues. Among other properties, the organic matter may exert a significant oxygen demand within the bed.

To a great degree, these conditions are specific to southeastern Washington and nearby areas. They are largely unfamiliar to field scientists, calling for new approaches, analytic procedures, and, probably, land management goals.

Riffles, Glides, Pools. Depending on the reach, 60 to 73 percent of the stream is riffle habitat, 14 to 27 is in glides and 2 to 5 percent comprises pools. The proportion of pools is very low, as might be expected in a braided stream with a mobile bed.

The lack of pools is a major constraint to the rearing of juvenile salmon and steelhead. Juvenile chinooks would especially benefit from an increase in the number or volume of pools. Additional pools in the upper portion of the river would increase juvenile salmonid populations by about 50 fish per new pool. More pools would also aid in reducing maximum daily temperatures.

Bed Surface. Perhaps the outstanding characteristic of the bed surface is its instability. Below Willow Creek, configurations of bars change slightly--but enough to adverse affect habitat values--at flows which occur many times during each winter and spring. The sizes of particles comprising the bed surface are equivalent in riffles and glides. In most other streams, the expected frequency of flows capable of mobilizing bar-surface gravels is about once per year; beds in riffles are commonly 1.5 to 2.0 times coarser than in glides.

Structure of the Bed. Frozen cores 18 to 20 inches long were extracted from the bed for description of their structure. Most cores exhibited 3 to 5 visibly-distinct horizons, distinguishable by texture or by the type and extent of interstitial matrix.

Virtually all horizons ranged from 2 to 10 inches in depth, with median thickness at each site being about 4 to 6 inches. The upper 1 to 7 inches often showed evidence of repeated flow-related disturbance. Thin, heterogeneous beds with abruptly textural changes, such as those observed in the Tucannon River, are typical of braided channels; beds of streams with a meander pattern have thicker horizons, generally of more uniform material, often graded.

Infiltration of Fine Sediment. Fine sediment gradually infiltrates into the clean coarse gravel and cobbles forming a freshly-made redd, and is deposited in the interstices. Flow through the gravels and oxygenation of eggs are reduced as the voids fill. Over a period of six weeks, we observed freshly-cleaned gravels to fill with fine material to a degree approaching adjacent portions of the bed which had not been cleansed. Dissolved oxygen levels in these artificial redds gradually were lowered over the six-week period. The extent of both infilling and oxygen depletion was greatest below Pataha Creek and smallest above Willow Creek.

Interstitial Environment. The velocity of water moving through the undisturbed gravels during the winter of 1979-80 ranged from about 80 to about 1400 centimeters per hour (about 60 to 1100 feet per day). The water contains high concentrations of fine sediment based on samples of water drawn from the bed during the following year in the lower half of the river. Generally, one to ten percent by weight of this fine sediment is finely-divided organic matter. Oxygen depletion is most closely correlated with the amount of fine material deposited in the redds, the organic matter

content of this material, and the organic solids remaining in suspension within the voids. Beginning in March, relatively warm waters in the gravel may aggravate the effects of oxygen depletion, and in the lower half of the stream occasionally exceed temperatures of 13.9°C (57°F), considered lethal for salmonid eggs.

Possible Management Directions.

Stabilizing the Banks and Bed. Central to serious enhancement of existing aquatic habitat is reversing the tendency toward increased braiding. Restoration of a more meandering pattern would result in a more stable bed, with more pools, lower velocities, and a bed composed of thicker and more uniform horizons with greater permeability and better water quality within the interstices. A meander pattern for the Tucannon River would be favored by more stable banks, and also by a lower magnitude and frequency of high runoff periods and by greater hydraulic roughness. Two apparent approaches are structural channelization of the stream and restoration of a riparian woodland sufficiently dense and wide to stabilize the banks. In either case, stabilizing the banks without reversing the tendency toward braiding would only partially improve habitat values, due to continuing high velocities, mobile beds, and lack of pools.

Reducing Summer Temperatures of the River. The Tucannon River is too warm to rear significant numbers of juvenile salmon or steelhead, or to support many trout of any species in its lower 32 miles. We believe this is an unnatural condition and that it began with the reduction of shade from riparian vegetation during

the large floods of 1964-65. The problem has been made worse by subsequent floods and continued channelization which minimize shade.

If water temperatures in the Tucannon River only down to Pataha Creek could be reduced to levels suitable for salmonids, an additional 95,000 yearling steelhead and 144,000 chinook salmon might be reared there. This would nearly double the present production of the river. Such estimates require the assumption, of course, that sufficient adults would be available to seed this reach of the stream. If the temperatures from Pataha Creek downstream to the mouth could be reduced to satisfactory levels, an additional 73,000 steelhead and 116,000 chinook could be reared - once again assuming that the reach could be well seeded.

Final Perspective. This study was authorized and designed based on the premise that fine sediment is the principal factor limiting use of the Tucannon River by salmonids. We learned that it is only one of several important controls, also including runoff, finely-divided organic matter, bank stability and channel form, and water temperatures. For the purposes of protecting aquatic resources, land treatment programs might aim at reducing runoff, soil erosion, and the loss of finely-divided crop residues. Habitat values in the stream also depend on conditions in the adjacent riparian corridor, notably bank stability and the extent of shading.

Many of the conditions and problems we encountered in the course of this study were unfamiliar to us, and, we believe, to most observers interested in the processes and resources of streams. Several merit serious additional study, among them:

1. Ground conditions affecting runoff and sediment yields of individual storms from loessial soils.
2. The sedimentology and hydrogeologic properties of sand-deficient, silt-rich streambeds in southeastern Washington and nearby areas.
3. Effects of high concentrations of finely-divided organic material on the physical and chemical properties of the bed.
4. The effects of very high relative velocities of flow (Froude number approaching or exceeding 1.0) on the stability of non-cohesive beds and banks, lacking large roughness elements, and the role of dikes and revetments in such environments.

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APPENDIX A

MONITORING STATIONS

AND

INSTRUMENTATION

TUCANNON RIVER STUDY, WY1980

Designation	Stream and Station[a]	Instrumentation[b]								Remarks
		WLR	SG	CG	SSS	LSM	DO	SD	SL	
P79G-A	Tucannon River at the fish hatchery bridge	✓	✓	✓	✓	✓	✓	✓	✓	1. Habitat station slightly upstream of bridge 2. Hatchery staff appraised of full range of our program
P79G-B	Tucannon River at Krous Ranch ("Riverview Park")		✓	✓	✓	✓	✓	✓	✓	
P79G-C	Pataha Creek at Pomeroy		✓	✓	✓					1. Pre existing staff gage 2. Level survey not needed
P79G-D	Pataha Creek at Chard Road	✓	✓	✓	✓	✓				
P79G-E	Tucannon River at Smith Hollow Road	✓	✓	✓	✓	✓	✓	✓	✓	1. USGS Gage 2. Proposed automatic sampler site
P79G-F	Tucannon River at Powers Road		✓	✓	✓	✓			✓	
P79G-G	Tucannon River above Marengo at Horrid Ranch						✓	✓	✓	
P79G-H	Tucannon River at Camp Wooten bridge						✓	✓	✓	1. USFS discharge and suspended sediment station

[a]Water quality monitoring to occur at stations A through F, including regular measurements of nitrate, conductivity, and other constituents as indicated.

[b]Instrumentation abbreviations

WLR - Water Level Recorder (A-35's provided by SCS)
SG - Staff Gage, calibrated in 0.01 feet and rated by discharge measurement
CG - Crest-stage Gage, calibrated in 0.01 feet and at same datum as staff gage
SSS - Single Stage Samplers for rising-limb suspended sediment sampling
LSM - Level Survey Monuments, usually re-bar pins, surveyed and relocatable using sketch maps
DO - Dissolved Oxygen samplers, described in text
SD - Scour devices, arrays of ping pong balls or styrofoam balls connected by monofilament
SL - Scour lines, mapped bank pins for repeatable cross-sections of bed elevations.

Monitoring Stations and Instrumentation, Tucannon River Water Quality and Stream Habitat Study.

APPENDIX B

DAILY STREAMFLOW RECORDS

TUCANNON RIVER BASIN 1979-1980

Water Year	1980
Stream	Tucannon River
Station	Tucannon Hatchery

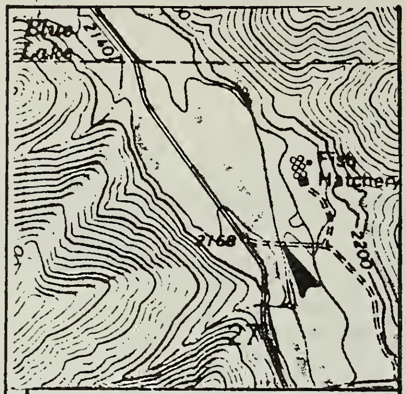
ANNUAL DISCHARGE RECORD

P79G-A

Station Location

SW¼ of NE¼, Sec. 27, T10N, R41E. On west abutment, beneath bridge to Tucannon Fish Hatchery, approximately 15 miles SW of Pomeroy, WA, in Columbia County.

Map



Topo Quad: Hopkins Ridge, WA

Scale: 1:24000

Watershed Descriptors

Wilderness and grazed areas, with moderate road network; minor logging activity. Major fresh landslide in Bear Creek tributary reported by Murray Johnson, USFS. Hatchery diverts a constant flow of 10.0 cfs from Tucannon River above Rainbow Lake, which is discharged below gage. Drainage area = 89 square miles.

Extreme Flows

Date	Time	Gage Ht.	Discharge	Notes
1/14	0900	1.08	340	
4/21	-	0.78	235	
4/29	-	0.88	278	
5/6	-	0.90	285	
6/12	2000	0.73	215	

Gaging Record

Station established Nov. 11, 1979. A-35 recorder installed Dec. 2, 1979. Measurements of suspended and bedload sediment transport, turbidity, NO_3+NO_2, specific conductance, temperature, size distribution of bed-surface material, sub-armor material, intra-gravel DO also made. Monitoring directed and sponsored by USDA, Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Summary
1	18.5	37.0	29.0	30.0	74.0	153.0	112.0	213.0	164.0	86.0	46.0	41.0	
2	18.5	37.0	45.0	30.0	78.0	150.0	110.0	223.0	159.0	84.0	42.0	43.0	
3	20.0	37.0	80.0	30.0	80.0	140.0	106.0	249.0	155.0	86.0	49.0	43.0	
4	21.5	38.0	102.0	30.0	79.0	149.0	106.0	249.0	154.0	83.0	49.0	47.0	
5	20.0	40.0	127.0	47.0	76.0	150.0	106.0	255.0	149.0	89.0	46.0	43.0	
6	22.0	40.0	95.0	65.0	75.0	140.0	110.0	285.0	148.0	83.0	44.0	43.0	
7	22.5	38.0	80.0	65.0	82.0	137.0	112.0	254.0	142.0	77.0	42.0	32.0	
8	22.5	38.0	78.0	75.0	72.0	128.0	110.0	230.0	139.0	70.0	54.0	36.0	
9	23.0	38.0	76.0	73.0	72.0	122.0	114.0	247.0	139.0	80.0	54.0	37.0	
10	22.0	39.9	90.0	65.0	72.0	119.0	120.0	247.0	137.0	88.0	47.0	36.0	
11	23.0	38.0	78.0	92.0	72.0	132.0	116.0	208.0	133.0	73.0	47.0	36.0	
12	24.5	38.0	77.0	185.0	72.0	125.0	116.0	211.0	162.0	71.0	44.0	37.0	
13	25.0	38.0	63.0	260.0	72.0	128.0	124.0	219.0	196.0	75.0	44.0	40.0	
14	25.0	38.0	61.0	270.0	72.0	144.0	143.0	210.0	187.0	71.0	40.5	40.0	
15	29.0	38.0	58.0	259.0	70.0	165.0	162.0	231.0	181.0	65.0	36.0	73.0	
16	37.0	38.0	58.0	254.0	68.0	158.0	172.0	220.0	168.0	60.0	34.0	58.0	
17	31.5	48.0	58.0	235.0	70.0	158.0	174.0	205.0	161.0	60.0	36.0	48.0	
18	32.5	53.0	58.0	211.0	94.0	153.0	184.0	200.0	154.0	58.0	52.0	47.0	
19	53.0	48.0	58.0	193.0	141.0	148.0	190.0	195.0	146.0	56.0	69.0	44.0	
20	49.0	43.0	55.0	163.0	164.0	148.0	205.0	194.0	138.0	56.0	63.0	47.0	
21	45.0	40.0	55.0	140.0	167.0	155.0	225.0	196.0	130.0	56.0	54.0	48.0	
22	42.0	41.5	53.0	120.0	157.0	148.0	215.0	200.0	130.0	54.0	49.0	58.0	
23	42.0	48.0	53.0	110.0	143.0	150.0	210.0	189.0	137.0	54.0	47.0	51.0	
24	43.0	46.0	53.0	97.0	131.0	150.0	207.0	179.0	125.0	49.0	44.0	47.0	
25	43.0	48.0	60.0	98.0	124.0	148.0	200.0	178.0	121.0	50.0	47.0	47.0	
26	50.0	46.0	58.0	74.0	124.0	141.0	190.0	194.0	121.0	50.0	46.0	47.0	
27	45.0	43.0	53.0	43.0	137.0	143.0	192.0	184.0	119.0	50.0	40.5	44.0	
28	42.0	37.0	50.0	30.0	157.0	132.0	200.0	182.0	110.0	53.0	42.0	44.0	
29	41.0	32.5	48.0	46.0	159.0	122.0	220.0	174.0	104.0	54.0	44.0	43.0	
30	41.0	38.0	48.0	36.0		128.0	218.0	170.0	100.0	47.0	42.0	43.0	
31	39.0		48.0	68.0		113.0		167.0		46.0	44.0		
Mean	32.7	40.8	64.7	112.7	101.9	141.2	159.0	211.5	143.6	65.6	46.4	44.8	97.0
Max	53.0	53.0	127.0	270.0	167.0	158.0	225.0	285.0	196.0	89.0	69.0	73.0	285.
Min	18.5	32.5	29.0	30.0	68.0	113.0	106.0	167.0	100.0	46.0	34.0	32.0	18.5
Total													
cfsd	1013.0	1223.0	2005.0	3494.0	2954.0	4377.0	4769.0	6558.0	4309.0	2034.0	1438.0	1343.0	35,517.
ac ft	2006.	2422.	3970.	6918.	5849.	8666.	9443.	12985.	8532.	4027.	2847.	2659.	70,324.

Monitor's Comments

1. Rating curve based on 11 measurements, and extended above 250 cfs.
2. Prior to Nov. 11, 1979 and during periods of no water level record, streamflow estimated by correlation to USGS gage on Tucannon River near Starbuck (site P79G-E).
3. Routine maintenance responsibilities assumed on Oct. 1, 1980 by Bill Hubbard, Washington Department of Game and Fish.

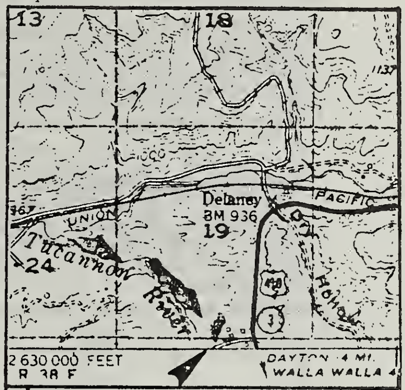
ANNUAL DISCHARGE RECORD

Water Year	1980
Stream	Tucannon River
Station	Krouse Ranch

Station Location

NE¼ of NW¼, Sec. 30, T12N, R39E, on old east abutment of county road bridge, 100 feet downstream of present bridge on Krouse Ranch; approximately 1.2 miles downstream of US12 crossing, 1.4 miles downstream of Willow Creek, and 1.3 miles upstream of Pataha Creek; 15 miles north of Dayton, WA, in Columbia County.

Map P79G-B



Topo Quad: Hay

Scale: 1: 62500

Watershed Descriptors

Includes wilderness and rangeland areas above gage P79G-A plus those in the Cummings and Tumalum basins. Most of watershed below Tumalum Creek used for agriculture with subordinate grazing. Virtually all of Willow Creek basin cultivated for wheat. Drainage area = 215 sq. miles.

Extreme Flows (Recorded peaks only)

Date	Time	Gage Ht.	Discharge	Notes
12/5	0800	0.68	172	Times are approx.
1/13	0100	1.11	280	
1/14	0900	1.64	560	
1/15	0100	1.79	640	
1/17	0400	1.68	590	
1/18	1000	1.32	440	
4/21	-	1.20	430	
5/6	-	1.35	450	
5/15	-	1.31	330	
5/30	1730	1.07	265	
6/16	3100±	3.45	1700±	

Gaging Record

Station established Nov. 9, 1979. Measurements of suspended and bedload transport, turbidity, NO_3+NO_2, specific conductance, temperature, size distributions of bed-surface material and sub-armor bed material, and intragravel DO also made. Monitoring directed and sponsored by USDA, Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Summary
1	53.0	76.0	76.0	86.0	102.0	200.0	135.0	309.0	198.0	95.0	62.0	62.0	
2	53.0	76.0	97.0	91.0	105.0	190.0	132.0	319.0	205.0	89.0	58.0	64.0	
3	57.0	76.0	106.0	91.0	107.0	172.0	130.0	319.0	188.0	95.0	64.0	64.0	
4	59.0	78.0	127.0	93.0	105.0	188.0	130.0	316.0	178.0	88.0	64.0	67.0	
5	57.0	80.0	152.0	123.0	104.0	190.0	130.0	316.0	170.0	90.0	63.0	64.0	
6	60.0	80.0	118.0	121.0	103.0	172.0	132.0	345.0	167.0	88.0	61.0	64.0	
7	60.0	78.0	107.0	115.0	108.0	168.0	135.0	345.0	163.0	83.0	60.0	56.0	
8	60.0	78.0	105.0	121.0	102.0	155.0	132.0	305.0	155.0	78.0	68.0	60.0	
9	61.0	78.0	104.0	127.0	102.0	150.0	137.0	323.0	145.0	85.0	68.0	61.0	
10	60.0	83.0	115.0	110.0	102.0	143.0	145.0	323.0	146.0	95.0	64.0	60.0	
11	61.0	73.5	99.0	109.0	102.0	163.0	140.0	299.0	143.0	81.0	64.0	60.0	
12	63.0	78.0	97.0	176.0	102.0	152.0	140.0	269.0	153.0	80.0	61.0	61.0	
13	64.0	78.0	91.0	259.0	102.0	155.0	150.0	269.0	230.0	82.0	61.0	62.0	
14	64.0	78.0	90.0	483.0	102.0	181.0	180.0	258.0	227.0	80.0	59.0	62.0	
15	68.0	78.0	88.0	553.0	100.0	215.0	211.0	282.0	218.0	75.0	54.0	83.0	
16	76.0	78.0	88.0	472.0	98.0	204.0	234.0	292.0	220.0	72.0	51.0	74.0	
17	71.0	85.0	87.0	350.0	100.0	204.0	240.0	272.0	310.0	72.0	54.0	68.0	
18	72.0	90.0	87.0	292.0	310.0	198.0	270.0	261.0	209.0	71.0	67.0	67.0	
19	82.0	85.0	87.0	240.0	250.0	187.0	282.0	255.0	185.0	70.0	78.0	66.0	
20	78.0	82.0	88.0	218.0	235.0	187.0	300.0	239.0	168.0	70.0	74.0	67.0	
21	83.0	79.0	88.0	172.0	220.0	200.0	358.0	230.0	160.0	70.0	68.0	68.0	
22	81.0	80.0	87.0	143.0	200.0	187.0	335.0	230.0	160.0	67.0	65.0	74.0	
23	81.0	85.0	86.0	134.0	180.0	190.0	320.0	227.0	167.0	67.0	64.0	70.0	
24	82.0	84.0	88.0	120.0	160.0	190.0	309.0	214.0	152.0	66.0	61.0	67.0	
25	82.0	85.0	93.0	120.0	150.0	187.0	295.0	212.0	146.0	66.0	64.0	67.0	
26	87.0	84.0	91.0	102.0	150.0	175.0	282.0	253.0	146.0	66.0	63.0	67.0	
27	83.0	82.0	88.0	84.0	166.0	180.0	286.0	228.0	142.0	66.0	59.0	66.0	
28	81.0	76.0	86.0	79.0	200.0	162.0	295.0	216.0	132.0	69.0	60.0	66.0	
29	80.0	72.0	85.0	86.0	205.0	148.0	350.0	215.0	128.0	67.0	61.0	64.0	
30	80.0	78.0	85.0	81.0		155.0	348.0	200.0	122.0	64.0	60.0	64.0	
31	78.0		85.0	99.0		137.0		218.0		63.0	61.0		
Mean	32.7	79.8	97.8	175.8	143.9	176.9	222.1	269.6	174.4	76.5	62.6	65.5	134.9
Max	87.0	90.0	152.0	553.0	310.0	215.0	358.0	345.0	310.0	95.0	78.0	83.0	553.
Min	53.0	72.0	29.0	81.0	98.0	137.0	130.0	200.0	122.0	63.0	51.0	56.0	51.0
Total													
csfd	2177.0	2393.0	3033.0	5450.0	4172.0	5485.0	6663.0	8359.0	5233.	2370.0	1941.0	1965.0	49240.
ac ft	4310.	4738.	6005.	10791.	8261.	10860.	13193.	16551.	10361.	4693.	3843.	3891.	97496.

Monitor's Comments

Shifting control section. Major shifts in rating curve on January 14, April 24-28, and June 16, 1980.
Streamflow estimated by correlation to USGS gage on Tucannon River near Starbuck during periods of no gage height observations and prior to establishment of Krouse gage.
Station affected by major thunderstorm runoff on June 16, 1980.

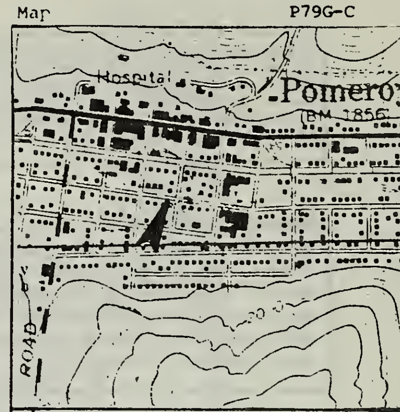
ANNUAL DISCHARGE RECORD

Water Year	1980
Stream	Pataha Creek
Station at	Pomeroy, WA

Station Location

SW¼ of SE¼, Sec. 31, T12N, R42E. On concrete wall comprising south bank of creek approximately 150 feet downstream of the Ninon St. bridge in Garfield County. Site of pre-existing staff gage reportedly emplaced by US Weather Bureau personnel.

Map P79G-C



Topo Quad: Pomeroy

Scale: 1:24000

Watershed Descriptors

Upper half of watershed, above Columbia Center, is predominantly forested uplands, with wilderness timber harvest and grazing activities. Agriculture and subordinate grazing are principal land uses in northern half of basin.
Drainage Area = 89 square miles.

Extreme Flows

Date	Time	Gage Ht.	Discharge	Notes
12/5	1000	0.32	40	
1/12	2030	0.90	77	
1/13	1500	1.00	86	
1/14	0530	2.10	168	
1/14	1630	2.30	184	
1/17	0000	0.48	58	
1/18	-	0.36	44	
2/3	2000	0.68	81	
4/29	-	0.47	56	Snowmelt + rain
5/30	-	1.32	150	Cloudburst
6/16	-	0.24	31	do

Gaging Record

Pre-existing staff plate. Single-stage samplers and crest-stage gage installed Nov. 6, 1979. Measurements of suspended and bedload sediment transport, turbidity, NO_3+NO_2, specific conductance, and temperature also made. Monitoring directed and sponsored by USDA Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Summary
1	2.0	4.2	11.0	14.9	10.0	24.5	20.0	36.0	18.2	10.5	5.8	2.6	
2	2.0	4.2	18.0	13.8	48.5	24.2	19.8	35.0	18.0	10.5	5.0	2.7	
3	2.2	4.2	14.5	17.6	62.5	24.2	20.0	34.0	17.9	11.1	6.3	2.7	
4	2.3	4.3	27.0	11.8	26.8	24.8	19.7	32.0	17.7	10.6	6.3	3.1	
5	2.2	4.6	18.0	16.4	16.8	24.8	19.7	30.0	17.9	10.6	5.8	2.7	
6	2.4	4.6	11.0	16.0	13.0	23.2	20.0	30.0	16.8	10.2	5.0	2.7	
7	2.4	4.3	8.8	15.8	14.5	23.7	19.7	29.5	16.3	10.2	4.7	2.2	
8	2.4	4.3	8.3	16.0	11.6	21.2	19.2	27.0	16.3	10.0	6.2	2.4	
9	2.5	4.3	8.5	17.0	10.4	21.5	19.4	30.0	14.5	11.2	6.2	2.5	
10	2.4	4.6	8.9	13.6	9.7	21.2	20.2	29.5	13.3	12.5	5.1	2.4	
11	2.5	4.3	9.1	13.0	9.7	22.5	21.0	27.0	12.5	10.4	5.1	2.4	
12	2.6	4.3	8.3	36.0	8.5	21.5	21.8	26.5	12.0	10.2	5.0	2.5	
13	2.7	4.3	9.2	68.0	9.7	21.5	21.2	26.8	20.0	10.6	5.0	2.6	
14	2.7	4.3	9.4	110.0	8.5	24.0	22.0	24.5	17.7	10.2	4.4	2.6	
15	3.2	4.2	9.3	53.0	8.5	23.8	25.0	29.5	18.5	9.1	3.9	5.8	
16	4.1	4.3	8.9	42.0	8.5	22.8	26.0	20.0	18.8	8.5	3.6	3.7	
17	3.4	6.7	9.4	33.5	5.6	22.8	27.0	23.5	16.0	8.5	3.9	3.1	
18	3.5	7.8	9.6	27.0	15.5	22.2	28.0	20.2	14.7	8.4	5.8	3.1	
19	7.7	5.2	9.3	18.0	22.0	21.7	28.0	20.2	14.0	8.2	9.9	3.0	
20	6.6	4.6	9.1	16.0	25.5	23.2	29.0	19.0	13.5	8.2	9.1	3.1	
21	5.6	4.6	8.6	20.0	25.5	24.2	29.0	18.0	13.3	8.2	5.8	3.1	
22	5.0	4.9	9.7	18.0	24.0	23.6	29.0	18.2	13.5	7.6	5.3	3.7	
23	5.0	6.1	10.1	16.0	23.0	23.8	29.0	17.5	15.7	7.6	5.1	3.3	
24	5.2	5.8	9.8	14.0	20.5	23.2	28.0	17.0	14.4	6.3	5.0	3.1	
25	5.2	5.2	9.4	13.0	19.5	22.8	43.0	17.3	13.5	6.4	5.1	3.1	
26	6.9	5.8	9.3	12.5	19.5	22.5	25.0	25.0	13.5	6.4	5.0	3.1	
27	5.6	5.2	9.2	11.5	21.5	22.4	25.0	22.0	13.3	6.4	4.4	2.8	
28	4.9	4.2	9.2	11.0	24.0	23.2	25.0	21.2	12.5	7.0	4.6	2.8	
29	4.8	3.3	8.9	10.0	23.5	21.5	47.0	16.0	11.2	7.2	5.0	2.7	
30	4.8	4.2	8.6	10.0		21.4	45.0	28.0	10.8	6.0	4.9	2.7	
31	4.6		8.9	10.0		20.6		20.0		5.7	5.0		
Mean	3.9	4.8	10.6	23.1	18.9	22.8	25.7	24.8	15.2	8.8	5.4	2.9	12.9
Max	7.7	7.8	27.0	119.0	62.5	24.8	47.0	36.0	18.8	12.5	9.9	5.8	110.
Min	2.0	3.3	8.3	10.0	5.6	20.6	19.2	17.0	10.8	5.7	3.6	2.7	2.0
Total													
csfd	119.4	143.0	327.0	715.4	547.0	708.5	771.7	769.4	456.3	274.5	167.3	88.3	4700.
ac ft	236.	283.	667.	1416.	1083.	1382.	1428.	1133.	612.	561.	331.	175.	9307.

Monitor's Comments

1. All instrumentation replaced Feb. 29, 1980 following extensive vandalism. Datum shift of +0.19 feet.
2. Reconstruction of high school and bridge 0.2 miles upstream of gage observed to contribute to sediment load and turbidity in May and June.
3. Discharge and water quality measured by Washington DOE in July, 1980.

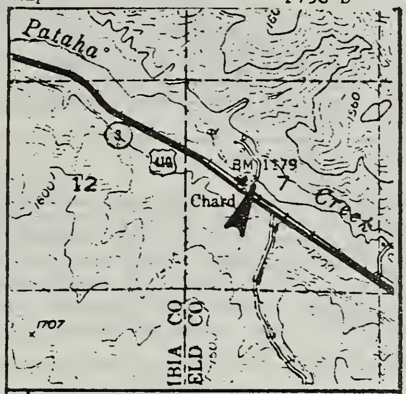
ANNUAL DISCHARGE RECORD

Water Year	1980
Stream	Pataha Creek
Station at	Chard Road

Station Location

SE¼ of NW¼, Sec. 7, T12N, R40E. On south abutment of Chard Road bridge, in Garfield County

Map P79G-D



Topo Quad: Hay, WA

Scale: 1:62500

Watershed Descriptors

Includes watershed of Pataha Creek at Pomeroy (P79G-C; drainage area = 89 sq. mi.). Intervening watershed primarily agricultural, with subordinate grazing uses. Limited belt of irrigated pasture and cropland adjacent to creek; some diversions and pumpage observed. Drainage area = 146 square miles.

Extreme Flows

Date	Time	Gage Ht.	Discharge	Notes
12/4	1200	0.90	48.5	
1/13	0030	1.55	228	
1/13	1700	1.70	310	
1/14	0900	2.55	990	
1/14	2130	2.80	1250	
1/17	0400	1.02	70	
4/21	1200	0.89	47	Snowmelt peak
4/23	1200	0.89	47	do
4/29	0830	0.89	47	Melt + rain
5/30	1740	1.39	158	Cloudburst
6/16	2350	1.17	96	do

Gaging Record

Station established November, 1979. A-35 recorder installed December 19, 1979. Measurements of suspended and bedload sediment transport, turbidity, NO_3+NO_2, specific conductance, and temperature also made. Monitoring directed and sponsored by USDA Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Summary
1	2.4	4.5	12.0	18.0	10.0	35.0	27.1	34.4	18.2	10.9	6.1	3.0	
2	2.4	4.5	23.0	16.2	87.0	34.5	26.2	33.1	17.8	10.9	5.4	3.2	
3	2.6	4.5	17.5	22.8	150.0	34.5	26.7	32.5	17.5	11.4	6.6	3.2	
4	2.7	4.7	40.0	13.3	39.0	35.5	26.4	30.7	17.4	11.0	6.6	3.5	
5	2.6	5.0	23.0	20.5	21.0	35.5	26.4	28.5	17.8	11.0	6.1	3.2	
6	2.8	5.0	12.0	20.0	15.0	32.5	26.7	29.0	16.8	10.8	5.4	3.2	
7	2.8	4.7	8.9	18.0	17.5	33.5	26.0	28.4	16.3	10.8	5.0	2.6	
8	2.8	4.7	8.3	20.0	13.0	29.2	25.4	25.8	16.2	10.5	6.5	2.8	
9	2.9	4.7	8.5	22.0	11.0	29.6	25.7	28.6	14.8	12.5	6.5	2.9	
10	2.8	5.0	9.0	16.0	10.0	29.2	27.2	28.2	13.3	14.5	5.5	2.8	
11	2.9	4.7	9.2	15.0	10.0	31.5	28.9	25.8	12.5	11.2	5.5	2.8	
12	3.0	4.7	8.4	34.1	8.5	29.0	29.6	25.2	13.2	10.8	5.4	2.9	
13	3.1	4.7	9.3	143.0	10.0	29.0	28.9	25.4	19.9	11.5	5.4	3.0	
14	3.1	4.7	9.8	282.0	8.5	34.0	31.0	23.3	17.7	10.8	4.8	3.0	
15	3.6	4.5	9.5	141.0	8.5	33.7	35.0	28.1	18.1	9.3	4.3	6.2	
16	4.5	4.7	9.0	49.4	8.5	31.7	38.0	26.6	18.3	8.6	4.0	4.1	
17	3.8	7.0	9.8	52.9	6.0	31.7	39.0	22.5	16.0	8.6	4.3	3.5	
18	3.9	8.0	10.0	40.0	19.0	30.6	41.0	20.5	14.7	8.5	6.1	3.5	
19	8.0	5.6	9.5	23.0	30.0	29.2	42.0	20.5	14.0	8.3	10.4	3.4	
20	7.0	5.0	9.3	20.0	36.0	32.6	43.0	19.0	13.5	8.3	9.3	3.5	
21	6.0	5.0	8.7	27.0	36.5	34.7	44.0	17.6	13.3	8.3	6.2	3.5	
22	5.4	5.3	10.0	23.0	34.0	33.0	44.5	18.1	13.5	7.8	5.7	4.1	
23	5.4	6.5	10.7	20.0	30.5	33.5	44.5	17.7	15.8	7.8	5.5	3.7	
24	5.6	6.2	10.2	17.0	27.5	32.5	41.0	17.0	14.4	6.6	5.4	3.5	
25	5.6	5.6	12.3	15.0	26.0	31.8	39.1	17.3	13.5	6.7	5.5	3.5	
26	7.2	6.2	11.0	14.0	26.0	31.2	36.5	24.4	13.5	6.7	5.4	3.5	
27	6.0	5.6	9.8	13.0	29.0	32.8	36.5	21.1	13.3	6.7	4.8	3.3	
28	5.3	4.5	9.3	12.0	34.0	29.6	36.5	20.0	12.5	7.3	5.0	3.3	
29	5.2	3.7	9.0	11.5	33.5	29.9	42.6	19.5	11.6	7.5	5.4	3.1	
30	5.2	4.7	8.7	11.0		29.1	40.8	25.7	11.0	6.3	5.3	3.1	
31	5.0		9.0	11.0		27.4		19.9		6.1	5.4		
Mean	4.3	5.1	11.8	37.6	27.4	31.9	34.2	24.3	15.2	9.3	5.8	3.4	17.2
Max	8.0	8.0	40.0	282.0	150.0	35.5	44.5	34.4	19.9	14.5	10.4	6.2	282.0
Min	2.4	3.7	8.3	11.0	6.0	27.4	25.4	17.	11.0	6.1	4.8	2.6	2.4
Total													
csfd	131.6	154.2	365.0	1164.6	796.0	987.5	1026.2	754.4	456.4	288.0	178.8	100.9	6312
ac ft	261.	305.	723.	2306.	1576.	1924.	2037.	1497.	709.	606.	354.	200.	12501.

Monitor's Comments

1. Station affected by anchor ice, December 9-January 12, January 15-February 3. Ice failure on February 3 damaged installation.
2. Tumbleweed growth in stilling well caused lost record, June 28-August 12.
3. Maintenance of recorder assumed October 1, 1980 by SCS, Spokane, WA.

Water Year	1980
Stream	Tucannon River
Station	Smith Hollow Road (near Starbuck)

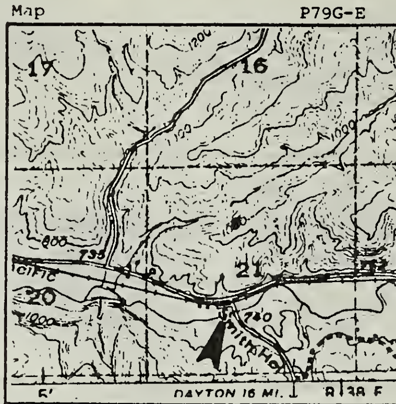
ANNUAL DISCHARGE RECORD

Station Location

NE¼ of SW¼, Sec. 21, T12N, R38E. Approximately 3 miles east of Starbuck, WA, and 0.4 miles below mouth of Smith Hollow. Site of USGS streamgage 13344500, "near Starbuck." Gaging station and low-flow measurements are approximately 150 ft. downstream of Smith Hollow Road bridge. High-flow measurements by HEA staff made from bridge.

Map

P79G-E



Topo Quad: Starbuck, WA

Scale: 1:62500

Watershed Descriptors

Includes watersheds of Tucannon River at Krouse Ranch (P79G-B) and Pataha Creek at Chard Road (P79G-D). Watershed above P79G-E and below these gages is primarily agricultural, with fallow-field wheat farming predominant in uplands; alfalfa and irrigated pasture along Tucannon River. Some summer diversions. Drainage area = 421 sq. mi.

Extreme Flows

Date	Time	Gage Ht.	Discharge	Notes
1/13	0100	2.28	678	
1/13	--	2.60	840	
1/14	1000	2.75	910	
1/15	0100	2.79	950	
2/3	0200	2.40	725	
2/18	2130	2.39	720	
4/29	1300	1.75	420	Snowmelt + rain
5/15	1500	1.57	344	do
6/16	--	3.70	1510	Cloudburst

Gaging Record

Streamflow (1958 to present), temperature (1963-1970), suspended sediment (1963-1970), and dissolved constituents (WY1973) by USGS. During WY1980, measurements of suspended and bedload sediment transport, temperature, turbidity and bedload size distribution also made by HEA staff. Monitoring directed and sponsored by USDA Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Summary
1	56.0	87.0	89.0	104.0	133.0	244.0	182.0	340.0	215.0	108.0	66.0	66.0	
2	56.0	87.0	106.0	110.0	140.0	231.0	180.0	351.0	212.0	106.0	62.0	68.0	
3	59.0	87.0	124.0	110.0	380.0	225.0	177.0	351.0	203.0	108.0	69.0	68.0	
4	61.0	89.0	136.0	112.0	180.0	221.0	177.0	344.0	194.0	104.0	69.0	72.0	
5	59.0	91.0	182.0	148.0	138.0	231.0	177.0	344.0	185.0	110.0	66.0	68.0	
6	62.0	91.0	143.0	146.0	136.0	221.0	180.0	375.0	182.0	104.0	64.0	68.0	
7	63.0	89.0	131.0	138.0	143.0	215.0	182.0	375.0	177.0	97.0	62.0	58.0	
8	63.0	89.0	124.0	146.0	128.0	203.0	180.0	332.0	169.0	89.0	74.0	62.0	
9	64.0	89.0	119.0	153.0	124.0	197.0	185.0	355.0	158.0	102.0	74.0	64.0	
10	62.0	87.0	131.0	133.0	122.0	191.0	194.0	351.0	155.0	108.0	67.0	62.0	
11	64.0	89.0	128.0	131.0	122.0	209.0	188.0	325.0	150.0	93.0	67.0	62.0	
12	66.0	89.0	122.0	265.0	119.0	200.0	188.0	292.0	161.0	91.0	64.0	64.0	
13	67.0	89.0	117.0	429.0	122.0	203.0	197.0	292.0	250.0	95.0	64.0	65.0	
14	67.0	89.0	112.0	710.0	119.0	228.0	225.0	281.0	244.0	91.0	61.0	65.0	
15	74.0	89.0	112.0	660.0	117.0	257.0	257.0	313.0	234.0	85.0	56.0	98.0	
16	86.0	89.0	117.0	504.0	115.0	247.0	274.0	317.0	271.0	80.0	54.0	82.0	
17	78.0	102.0	110.0	429.0	112.0	247.0	277.0	292.0	285.0	80.0	56.0	73.0	
18	80.0	108.0	110.0	359.0	348.0	244.0	303.0	281.0	215.0	78.0	72.0	72.0	
19	107.0	102.0	110.0	292.0	308.0	234.0	325.0	274.0	194.0	76.0	89.0	70.0	
20	102.0	95.0	110.0	257.0	271.0	234.0	347.0	257.0	185.0	76.0	83.0	72.0	
21	97.0	91.0	110.0	241.0	250.0	247.0	375.0	247.0	180.0	76.0	74.0	73.0	
22	93.0	93.0	110.0	209.0	244.0	234.0	375.0	247.0	169.0	72.0	69.0	82.0	
23	93.0	102.0	108.0	191.0	234.0	237.0	367.0	244.0	174.0	72.0	67.0	75.0	
24	95.0	100.0	106.0	174.0	209.0	237.0	351.0	228.0	163.0	69.0	64.0	72.0	
25	95.0	102.0	112.0	166.0	197.0	234.0	332.0	228.0	153.0	70.0	67.0	72.0	
26	104.0	100.0	110.0	133.0	197.0	221.0	317.0	281.0	153.0	70.0	66.0	72.0	
27	97.0	95.0	106.0	97.0	203.0	228.0	321.0	250.0	150.0	70.0	61.0	70.0	
28	93.0	87.0	104.0	83.0	225.0	209.0	332.0	237.0	139.0	74.0	62.0	70.0	
29	91.0	83.0	102.0	100.0	247.0	197.0	399.0	234.0	130.0	72.0	64.0	68.0	
30	91.0	89.0	102.0	89.0		203.0	395.0	231.0	125.0	67.0	62.0	68.0	
31	89.0		102.0	126.0		185.0		237.0		66.0	64.0		
Mean	78.5	92.3	116.3	224.0	185.6	223.0	265.3	293.7	185.5	85.8	66.4	70.0	157.6
Max	107.0	108.0	182.0	710.0	380.0	257.0	399.0	375.0	271.0	110.0	89.0	98.0	710.
Min	56.0	83.0	89.0	83.0	112.0	185.0	177.0	228.0	125.0	66.0	54.0	58.0	54.0
Total													
csfd	2434.0	2769.0	3605.0	6945.0	5383.0	6914.0	7959.0	9106.0	5575.0	2659.0	2059.0	2101.0	57508.
ac ft	4819.	5483.	7138.	13751.	10658.	13690.	15759.	18030.	11039.	5265.	4077.	4160.	113867.

Monitor's Comments

1. Daily discharge computations by USGS.

ANNUAL DISCHARGE RECORD

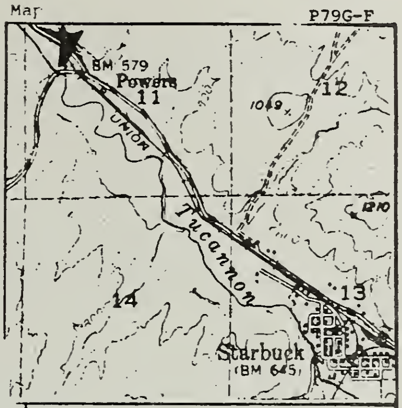
Water Year	1980
Stream	Tucannon River
Station	Powers Road

Station Location

SW¼ of NW¼, Sec. 11, T12N, R38E. Approximately 2 miles downstream of Starbuck and about 2 miles above Snake River, in Columbia County. Staff gage is 40 feet downstream of bridge, on right bank abandoned abutment. High flow measurements made from bridge.

Map

P79G-F



Topo Quad: Starbuck, WA

Scale: 1:62500

Watershed Descriptors

Includes watershed of Tucannon River at Smith Hollow Road (P79G-E; 421 sq. mi.). Intervening watershed is primarily agricultural, with fallow-field wheat farming predominant in uplands; alfalfa and irrigated pasture in bottomlands along river. Subordinate grazing. Major thunderstorm runoff event on June 16, 1980. Drainage area = 500 square miles.

Extreme Flows (Recorded peaks only)

Date	Time	Gage Ht.	Discharge	Notes
12/5	0500	0.26	210	All times are approx.
1/13	0200	0.98	710	
1/14	1000	1.45	1080	
1/15	-	1.43	1050	
1/18	-	1.01	735	
4/29	1245	0.60	415	
5/15	1530	0.49	340	
5/30	1220	0.38	275	
6/16	-	2.32	1500±	By correlation to Starbuck Gage

Gaging Record

Water quality measurements by USGS (and Washington Dept. of Ecology (During WY1980, REA staff also measured suspended and bedload sediment transport, turbidity, NO_2+NO_3, specific conductance, temperature, size distribution of bed-surface material and sub-armor gravels; intra-gravel DO also made. Monitoring directed and sponsored by USDA, Soil Conservation Service.

MEAN DAILY DISCHARGE OF WATER, OCTOBER, 1979 TO SEPTEMBER, 1980
(cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Water Year Summary
1	60.0	97.0	132.0	116.0	168.0	290.0	230.0	350.0	222.0	120.0	72.0	72.0	
2	60.0	97.0	154.0	122.0	172.0	285.0	230.0	360.0	220.0	118.0	67.0	74.0	
3	64.0	97.0	145.0	122.0	400.0	285.0	230.0	360.0	210.0	120.0	75.0	74.0	
4	66.0	99.0	150.0	125.0	250.0	280.0	230.0	348.0	204.0	116.0	75.0	79.0	
5	64.0	101.0	176.0	166.0	200.0	280.0	226.0	350.0	193.0	122.0	72.0	74.0	
6	67.0	101.0	138.0	165.0	198.0	275.0	226.0	385.0	191.0	106.0	70.0	74.0	
7	68.0	99.0	125.0	155.0	233.0	275.0	233.0	385.0	183.0	108.0	67.0	63.0	
8	68.0	99.0	125.0	165.0	190.0	275.0	230.0	343.0	175.0	100.0	81.0	67.0	
9	70.0	99.0	150.0	175.0	152.0	270.0	226.0	365.0	165.0	112.0	81.0	70.0	
10	67.0	97.0	145.0	150.0	149.0	268.0	220.0	358.0	162.0	120.0	73.0	67.0	
11	70.0	99.0	132.0	148.0	138.0	260.0	205.0	338.0	158.0	103.0	73.0	67.0	
12	72.0	99.0	132.0	314.0	138.0	255.0	205.0	318.0	169.0	100.0	70.0	70.0	
13	73.0	99.0	132.0	475.0	132.0	258.0	215.0	295.0	259.0	105.0	70.0	71.0	
14	73.0	99.0	132.0	762.0	128.0	275.0	235.0	283.0	250.0	100.0	66.0	71.0	
15	80.0	97.9	132.0	740.0	125.0	297.0	265.0	318.0	242.0	94.0	60.0	108.0	
16	95.0	99.0	132.0	585.0	122.0	261.0	285.0	321.0	280.0	88.0	58.0	90.0	
17	85.0	112.0	132.0	470.0	120.0	260.0	290.0	300.0	290.0	88.0	60.0	80.0	
18	88.0	120.0	132.0	375.0	390.0	250.0	315.0	290.0	225.0	85.0	80.0	79.0	
19	120.0	112.0	137.0	320.0	340.0	250.0	335.0	280.0	200.0	82.0	100.0	77.0	
20	112.0	108.0	137.0	282.0	305.0	265.0	350.0	265.0	193.0	82.0	91.0	79.0	
21	108.0	101.0	155.0	260.0	285.0	273.0	390.0	255.0	188.0	82.0	81.0	80.0	
22	102.0	102.0	138.0	239.0	282.0	260.0	385.0	255.0	175.0	78.0	75.0	90.0	
23	102.0	112.0	125.0	220.0	279.0	265.0	378.0	252.0	182.0	78.0	73.0	82.0	
24	105.0	110.0	132.0	205.0	245.0	265.0	365.0	235.0	172.0	75.0	70.0	79.0	
25	105.0	108.0	147.0	200.0	235.0	250.0	336.0	235.0	162.0	76.0	73.0	79.0	
26	115.0	110.0	137.0	150.0	235.0	245.0	325.0	290.0	162.0	76.0	72.0	79.0	
27	108.0	105.0	132.0	108.0	240.0	253.0	330.0	260.0	159.0	76.0	66.0	77.0	
28	102.0	97.0	130.0	92.0	260.0	260.0	340.0	245.0	146.0	81.0	67.0	77.0	
29	100.0	91.0	120.0	112.0	280.0	245.0	405.0	241.0	137.0	78.0	70.0	74.0	
30	100.0	99.0	120.0	100.0		242.0	400.0	240.0	132.0	73.0	67.0	74.0	
31	99.0		120.0	142.0		236.0		245.0		72.0	70.0		
Mean	86.1	102.2	136.0	250.3	220.4	265.9	293.0	302.1	193.5	94.0	72.4	76.6	174.5
Max	120.0	120.0	176.0	762.0	400.0	290.0	405.0	385.0	290.0	122.0	100.0	108.0	762.
Min	60.0	91.0	120.0	92.0	120.0	236.0	205.0	235.0	132.0	72.0	58.0	63.0	58.0
Total cfs	2668.0	3066.0	4226.0	7760.0	6391.0	8224.0	8789.0	9365.0	5806.0	2914.0	2245.0	2297.0	63679.
ac. ft.	5283.	6071.	8367.	15365.	12654.	16284.	17402.	18543.	11496.	5770.	4445.	4548.	126084.

Hydrologist's Comments

1. Major changes in bed configuration observed following most major storms. Four rating curves used during WY1980.
2. Bed configuration changes during June 16-17 event preclude use of stage-discharge curve.

APPENDIX C

MONTHLY VARIATION IN DISCHARGE,

TUCANNON RIVER NEAR STARBUCK,

1959 THROUGH 1978

Monthly Variation in Discharge: Tucannon River Near Starbuck[a]

Water Year	October	November	December	January	February	March	April	May	June	July	August	September	Average	Index[b/]
1958-1959	72.5	173	319	334	260	233	280	265	219	83.9	72.3	96.0	200	1.12
1959-1960	125	137	132	107	183	237	290	249	160	71.7	67.1	69.3	152	0.85
1960-1961	78.9	106.4	103.3	160	308	299	226	264	211	71.4	53.1	72.9	163	0.92
1961-1962	80.0	93.8	139.7	187	138	211	308	266	193	81.7	62.0	68.8	152	0.85
1962-1963	105.5	120.8	169.7	102	300	170	222	184	89.3	49.4	48.6	57.1	135	0.76
1963-1964	67.0	88.6	109.5	144	151	145	263	265	270	89.5	60.8	64.2	143	0.80
1964-1965	72.7	91.2	672.7	617	505	263	290	342	224	95.6	76.6	78.7	277	1.56
1965-1966	79.3	87.1	90.3	130	112	194	270	221	116	63.4	49.0	71.8	124	0.70
1966-1967	77.5	95.8	120.4	189	166	162	162	295	190	65.7	48.6	53.4	135	0.76
1967-1968	79.7	88.6	110.9	134	228	167	134	146	101	51.5	52.5	69.4	114	0.64
1968-1969	87.2	134.4	153.8	528	249	319	465	442	181	79.7	62.6	66.2	231	1.30
1969-1970	84.0	87.5	99.4	314	277	227	180	263	227	77.5	55.1	72.7	164	0.92
1970-1971	85.2	117.3	141.5	352	257	220	271	404	311	104	66.3	89.3	202	1.13
1971-1972	99.2	115.1	202.8	300	456	717	311	455	335	119	80.5	108	275	1.54
1972-1973	104.3	115.8	195.5	199	137	157	145	165	86.7	50.8	43.7	63.9	122	0.69
1973-1974	78.5	172.9	318.9	635	353	359	498	495	599	203	114	97.7	327	1.84
1974-1975	97.2	116.5	134.2	381	290	299	240	399	326	130	95.2	82.8	216	1.21
1975-1976	106.3	135.5	362.5	386	251	290	400	427	249	119	108	89.2	244	1.37
1976-1977	97.3	111.4	110.4	98.1	103	103	114	93.9	70.1	50.3	48.8	77.1	89.8	0.50
1977-1978	84.4	108	264	181	188	213	235	207	120	90.4	72.4	89.4	154	0.87
Average	83.6	109	171	240	251	252	280	310	221	86.7	61.3	70.7	178	
Maximum	106.3	172.9	672.1	635	505	359	498	495	599	130	114	108		
Minimum	67.0	87.1	90.3	98.1	103	103	114	93.9	70.1	49.4	43.7	53.4		

[a] Gage Number 13344500. Monthly records available from October 1914 to September 1917, August 1928 to September 1931. Daily records available from October 1958 to current year.

[b] Runoff index is the ratio of runoff for the year to the mean annual runoff for the 20-year period.

APPENDIX D

BEDLOAD SAMPLING RESULTS, 1979-1980

Table D-1. Bedload Sampling Results, 1979-1980

Tucannon River at Tucannon Hatchery

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c/] (mm)
791110	1430	0.16	52.5	1.88	28	10	30	300	9.8	0.008	0.35		
791206	1130	0.27	80.0	2.20	29	10	30	300	0.8	0.0007	0.03		
791223	1130	0.16	52.5	1.88	28	10	60	600	0.7	0.0002	0.01		
800115	1540	1.00	335	4.00	60	5	120	600	255.3	0.22	9.71		
800115	1550	1.00	335	4.00	60	5	120	600	181.4	0.16	6.89		
800420	1730	0.78	235	3.45	56	10	90	900	132.4	0.07	3.13		
800422	1130	0.78	235	3.45	58	10	90	900	5.0	0.0027	0.12		
800428	0900	0.80	240	3.49	58	10	90	900	232.8	0.13	5.70		
800430	1030	0.80	240	3.49	58	10	90	900	76.1	0.04	1.86		
800505	1515	0.80	240	3.49	58	12	60	720	491.2	0.35	15.04		
800506	1600	0.90	286	3.80	60	10	90	900	111.8	0.065	2.83		
800509	1400	0.82	252	3.57	58	10	60	600	38.3	0.03	1.41		
800516	1700	0.73	215	3.30	52	10	90	900	9.7	0.005	0.21		
800529	1415	0.61	173	3.08	55	20	30	600	5.2	0.004	0.18		
800601	1015	0.58	164	2.99	55	20	30	600	3.7	0.003	0.13		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-2

Bedload Sampling Results, 1979-1980

Tucannon River at Krouse Ranch

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates		Bedload Sizes	
										(lb/sec)	(ton/day)	D50 (mm)	Dmax[c/] (mm)
791111	1200	0.11	55	1.80	35	20	30	600	2.47	0.001	0.05		
791223	1235	0.36	131	2.76	37	10	60	600	1.04	0.0004	0.02		
800101	0725	0.36	82	2.12	37	10	60	600	0.84	0.0004	0.02		
800112	1100	0.60	140	2.83	39	10	60	600	8.77	0.005	0.22		
800112	1620	0.84	220	3.61	40	10	60	600	Sample was not analyzed				
800113	1105	1.04	320	4.45	40	5	120	600	1761.7	1.04	44.8	37.0	45-62.5
800115	1155	1.62	580	7.90	42	5	120	600	2152.3	1.26	54.4	16.4	45-62.5
800118	1450	1.04	320	4.45	40	5	120	600	1338.8	0.78	34	37.1	45-62.5
800316	1415	0.70	170	1.20	38	12	90	1080	4.4	0.001	0.06		
800420	1615	1.00	300	4.21	39	10	90	900	305.8	0.116	5.04		
800421	1530	1.07	340	4.55	39	20	40	800	2408.0	1.04	45	29.9	45-62.5
800423	1230	1.00	300	4.21	39	10	60	600	389.0	0.22	9.61	28.4	45-62.5
800427	1245	1.00	300	4.21	39	10	60	600	274.0	0.15	6.77		
800428	1430	0.99	294	4.20	39	10	60	600	601.1	0.34	14.87		
800429	1330	1.30	440	5.78	40	6	60	360	6054.1	5.91	255.7		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-2 (continuation)

Bedload Sampling Results, 1979-1980

Tucannon River at Krouse Ranch

Date	Time (hrs)	Gage Height (ft)	Discharge[a] (cfs)	Mean[b] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c] (mm)
800430	1330	1.26	420	5.58	40	6	60	360	2645.9	2.59	111.8		
800501	1545	1.03	315	4.30	39	10	60	600	264.6	0.15	6.54		
800506	1015	1.31	415	5.80	40	6	60	360	4820.6	4.72	203.6	21.11	45-62.5
800506	1415	1.35	450	6.00	40	6	60	360	2875.4	2.8	121.5	45.89	45-62.5
800508	1130	1.25	330	5.40	40	6	60	360	1115.4	1.09	47.11	33.13	32-45
800509	1020	1.35	355	6.00	40	6	60	360	1734.5	1.70	73.3	29.86	45-62.5
800514	1600	1.08	255	4.60	39	10	60	600	19.2	0.01	0.47		
800515	1400	1.25	330	5.42	39	10	60	600	143.9	0.08	3.56		
800529	2100	0.98	218	4.18	39	10	60	600	40.47	0.023	1.00		
800530	2100	0.98	218	4.18	39	20	30	600	1.6	0.0009	0.04		
800531	1050	0.91	200	3.75	38	20	30	600	1.07	0.0006	0.03		
800531	2115	0.86	186	3.40	38	20	30	600	1.05	0.0006	0.03		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used.

Table D-3

Bedload Sampling Results, 1979-1980

Pataha Creek at Pomeroy

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c/] (mm)
800105	1135	0.10	19	1.64	15.5	5	60	300	10.0	0.004	0.20		
800112	1830	0.78	55	2.85	18.0	10	60	600	40.1	0.01	0.46		
800113	0840	0.48	53	2.60	17.8	10	60	600	466.3	0.12	5.26		
800114	1130	0.90	78	3.90	18.0	5	120	600	Sample not analyzed				
800420	1120	0.37	45.5	2.52	17.5	6	30	180	24.4	0.02	0.90		
800421	1700	0.39	48	2.65	17.8	6	60	360	34.4	0.0015	0.65		
800422	1800	0.38	47	2.60	18.0	6	60	360	41.9	0.018	0.80		
800423	1930	0.37	45.5	2.52	17.5	6	60	360	28.4	0.012	0.52		
800427	0800	0.36	44	2.50	17.5	6	60	360	22.0	0.009	0.41		
800428	0900	0.37	45.5	2.52	17.5	6	60	360	70.7	0.03	1.31		
800429	0830	0.45	53	2.72	17.5	6	60	360	49.5	0.02	0.91		
800430	0830	0.40	49	2.55	17.5	6	60	360	46.1	0.019	0.85		
800502	0830	0.30	38	2.30	17.5	6	60	360	47.1	0.02	0.87		
800506	0800	0.26	33.5	2.18	17	6	60	360	32.2	0.013	0.58		
800508	0800	023	30.5	2.10	17	6	60	360	23.7	0.009	0.43		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-3 (continuation)

Bedload Sampling Results, 1979-1980

Pataha Creek at Pomeroy

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload D50 (mm)
800509	0900	0.25	32.5	2.14	17	6	60	360	67.4	0.028	1.21	
800514	1000	0.15	22.5	1.78	16	6	60	360	2.2	0.0001	0.04	
800515	1800	0.24	31.0	2.10	17	6	60	360	50.4	0.02	0.90	
800530	1745	0.15	22.5	1.78	16	10	60	600	6.3	0.001	0.06	
800531	1750	0.12	18	1.60	17.5	10	60	600	14.8	0.0037	0.16	

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-4

Bedload Sampling Results, 1979-1980

Pataha Creek at Chard Road

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c/] (mm)
800113	0955	1.19	102.	3.16	23.8	10	60	600	56.8	0.019	0.86		
800420	1330	0.86	43	1.98	22	9	60	540	5.0	0.002	0.08		
800423	1130	0.88	46.5	2.07	22.5	6	60	360	4.1	0.023	0.10		
800425	1230	0.83	39	1.89	22	6	60	360	3.4	0.002	0.08		
800427	1020	0.80	36.5	1.82	21.5	6	60	360	3.0	0.002	0.07		
800428	1730	0.80	36.5	1.82	21.5	6	60	360	5.6	0.003	0.13		
800429	1100	0.87	45	2.03	22	6	60	360	7.4	0.004	0.17		
800430	1630	0.83	39	1.89	22	5	60	300	41.8	0.027	1.17		
800506	0930	0.72	29	1.61	21	6	60	360	4.0	0.009	0.40		
800508	0930	0.68	26	1.51	20	6	60	360	2.6	0.001	0.05		
800509	1000	0.70	27.5	1.56	20	6	60	360	3.1	0.002	0.07		
800514	1100	0.64	23	1.42	19	6	60	360	1.7	0.001	0.03		
800515	1700	0.71	28.0	1.58	17.5	6	60	360	9.6	0.004	0.18		
800521	1615	0.89	47	2.09	22	8	60	480	1.7	0.001	0.03		
800530	1845	1.17	95	3.06	24	10	30	300	36.6	0.02	1.02		

a/ Mean discharge for the p riod of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-4 (continuation)
Bedload Sampling Results, 1979-1980
Pataha Creek at Chard Road

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload S D50 (mm)
800530	1800	0.94	54	2.23	21.5	10	60	600	25.2	0.007	0.34	
800531	0945	0.60	21	1.33	20.0	15	30	450	3.3	0.01	0.06	
800531	1550	0.58	20	1.30	21.0	15	30	450	2.2	0.001	0.04	
800601	1115	0.56	18	1.23	20.5	10	30	300	0.57	0.0002	< 0.01	

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-5

Bedload Sampling Results, 1979-1980

Tucannon River at Smith Hollow Road
(USGS Gage)

Date	Time (hrs)	Gage Height (ft)	Discharge[a/] (cfs)	Mean[b/] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c/] (mm)
791223	1330	0.80	110	2.31	42	10	60	600	10.1	.0062	0.27		
800103	1445	0.86	122	2.42	42	10	60	600	12.4	.0076	0.33		
800112	1535	0.86	350	4.00	44	5	120	600	66.3	.043	1.85		
800113	1150	1.74	400	4.29	44	5	60	300	25.9	0.033	1.44		
800114	1505	2.22	630	5.32	44	5	120	600	1878.7	1.21	52.4	17.1	45-64
800311	0930	1.18	210	3.15	43	-	-	600	29.67	0.019	0.83		
800420	1530	1.58	350	4.00	44	10	90	900	72.3	0.031	1.35		
800421	1100	1.65	380	4.15	44	10	90	900	2886.1	1.24	53.8	15.8	32-45
800423	1515	1.63	375	4.15	44	10	60	600	1572.4	1.00	43.3	13.3	45-64
800427	1135	1.51	315	3.81	44	10	60	600	26.9	0.017	0.75		
800428	1400	1.55	338	3.95	44	10	60	600	57.6	0.037	1.61		
800429	1140	1.74	410	4.30	44	10	60	600	378.8	0.24	10.6		
800430	1500	1.69	390	4.25	44	10	60	600	298.4	0.19	8.32		
800501	1630	1.53	325	3.85	44	10	60	600	195.0	0.13	5.44		
800506	1130	1.64	375	4.15	44	6	60	360	267.0	0.17	7.44		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-5 (continuation)

Bedload Sampling Results, 1979-1980

Tucannon River at Smith Hollow Road

Date	Time (hrs)	Gage Height (ft)	Discharge[a] (cfs)	Mean[b] Velocity (ft/sec)	Active Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c] (mm)
800508	1100	1.65	380	4.20	44	10	60	600	282.1	0.18	7.86		
800509	1100	1.65	380	4.20	44	6	60	360	258.5	0.27	12.01		
800514	1220	1.42	286	3.65	44	10	60	600	297.4	0.19	8.29	22.8	22.4-32
800515	1500	1.56	340	3.95	44	10	60	600	607.3	0.39	16.93	24.2	32-45
800529	0715	1.25	230	3.30	43	20	30	600	152.3	0.095	4.15		
800530	1530	1.20	215	3.19	43	20	30	600	3.3	0.0001	0.0063		
800531	1500	1.20	215	3.19	43	20	30	600	2.9	0.0001	0.0055		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

Table D-6

Bedload Sampling Results, 1979-1980

Tucannon River at Powers Road

Date	Time (hrs)	Gage Height (ft)	Discharge[a] (cfs)	Mean[b] Velocity (ft/sec)	Active[d] Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax[c] (mm)
791112	1245	0.07	97	3.42	41	10	30	300	6.1	0.0073	0.32		
791220	1530	0.11	165	3.80	44	10	30	300	133.4	0.17	7.44		
791223	1420	0.10	133	3.75	42	10	60	600	22.3	0.013	0.59		
800112	1450	0.54	375	*	110	5	120	600	456.3	0.73	31.8		
800114	1730	1.12	860	*	125	5	120	600	164.0	0.30	13.0		
800316	1305	0.37	260	4.38	50	10	90	900	381.7	0.19	8.06		
800420	1430	0.50	350	3.72	92	10	90	900	62.2	0.056	2.42		
800421	1345	0.52	360	3.76	95	10	60	600	186.4	0.26	11.2		
800423	1530	0.49	345	3.60	92	10	60	600	248.8	0.32	14.5		
800424	1545	0.49	345	3.60	92	10	60	600	908.8	1.23	53.0		
800429	1230	0.60	415	3.85	100	10	60	600	911.6	1.33	57.9		
800430	1545	0.61	420	3.88	100	10	60	600	449.3	0.66	28.5		
800506	1215	0.59	410	*	110	6	60	360	1791.0	4.82	208		
800508	1030	0.50	350	3.63	102	10	60	600	160.4	0.24	10.37		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

d/ Samples taken at three different cross-sections and from bridge. Active bed widths and mean velocities vary substantially at each section

* Data not adequate to establish mean velocities beneath the bridge

Table D-6 (continuation)

Bedload Sampling Results, 197901980

Tucannon River at Powers Road

Date	Time (hrs)	Gage Height (ft)	Discharge a/ (cfs)	Mean b/ Velocity (ft/sec)	Active d/ Bed Width (ft)	Sampled Points	Time/Point (sec)	Total Time (sec)	Sample Dry Weight (g)	Bedload Transport Rates (lb/sec)	Bedload Transport Rates (ton/day)	Bedload Sizes D50 (mm)	Bedload Sizes Dmax c/ (mm)
800509	1215	0.58	400	*	110	8	60	480	468.5	0.94	40.9		
800514	1400	0.39	280	4.46	48.5	10	60	600	185.0	0.13	5.68		
800515	1615	0.49	345	3.60	95	10	60	600	625.1	0.87	37.6		
800529	0630	0.28	220	3.80	54	20	30	600	18.0	0.014	0.62		
800530	1130	0.26	210	3.80	53	20	30	600	231.1	0.18	7.74		
800530	1440	0.31	235	3.95	54	20	30	600	19.5	0.015	0.64		
800530	1450	0.27	215	3.86	55	20	30	600	12.6	0.010	0.44		
800531	1300	0.28	220	3.78	53.5	20	30	600	125.07	0.098	4.24		

a/ Mean discharge for the period of bedload sampling, from stage-discharge relation

b/ Mean channel velocity, computed from at-a-station hydraulic geometry

c/ Indicates the largest sieve opening on which material was retained, and the next sieve opening used

d/ Samples taken at three different cross-sections and from bridge. Active bed widths and mean velocities vary substantially at each section

* Data not adequate to establish mean velocities beneath the bridge

APPENDIX E

PARTICLE SIZES OF SEDIMENT IN SUSPENDED TRANSPORT, TUCANNON RIVER AND SELECTED NEARBY STREAMS

Particle Sizes of Sediment in Suspended Transport During High-Recurrence Storms
Tucannon River and Selected Nearby Streams[a]

USGS Station No.	Stream, Location	Date	Discharge (cfs)	Suspended Concentration (mg/1)[b]	Sediment Transport Rate (tpd)[c]	Particle Sizes: Clay[d] (%)	Particle Sizes: Silt[e] (%)	Particle Sizes: Sand[f] (%)
13343680	Deadman Creek near Central Ferry, WA	12/23/64		460,000[g]				
		12/22/64	1400	265,000	990,000	13	75	12
		12/23/64	350	326,000	305,000	20	76	4
		01/27/65	365	27,900	27,000	19	75	6
13343800	Meadow Creek near Central Ferry, WA	12/22/64		428,000[g]				
13343500	Tucannon River near Starbuck	12/22/64		255,000[g]				
		12/22/64	6760	220,000	4,040,000	14	77	9
		01/27/65	1240	13,800	46,200	18	72	10
		01/28/65	1930	23,300	119,000	20	72	8
		01/30/65	4060	21,500	235,000	16	66	18
14016640	East Fork Touchet River at Dayton, WA	12/01/64	296	1,300	1,040	21	72	7
		12/24/64	888	5,700	13,700	12	66	22
14016800	Patit Creek near Dayton, WA	12/01/64	52	3,450	484	37	61	2
14017000	Touchet River at Bolles, WA	12/02/64	1550	3,440	14,400	19	75	6
		12/22/64	6110	7,230	119,000	27	71	2
		12/22/64	6750	7,730	141,000	15	75	10
		01/27/65	1320	5,880	21,000	20	73	7
		01/29/65		25,500[g]				
		01/30/65	4350	7,600	89,300	19	72	9
14012000	Walla Walla River at Milton, OR	12/02/64	965	531	1,380	15	44	41
		12/23/64	2380	7,720	49,600	18	56	26
14013600	Mill Creek, below Blue Creek, near Walla Walla, WA	12/01/64	1090	4,260	12,500	24	61	15
		12/22/64	1890	12,800	65,300	21	65	14
		12/23/64		16,300[g]				
		01/30/65	2200	1,660	10,100	18	62	20

[a]Data from various USGS publications. Streams selected to present a range of typical southeastern Washington watersheds and also based on sampling frequency. All size analyses for a given stream from the 1964-65 storm period are presented.

[b]Concentration expressed as milligrams per liter, converted from the initial published values (in parts per million) using standard factors (Guy, 1969).

[c]Instantaneous transport rate in tons per day.

[d]Particles finer than 0.004 mm.

[e]Particles of 0.004 to 0.063 mm.

[f]Particles coarser than 0.063 mm.

[g]Instantaneous maximum concentration during the 1964-65 storms, as estimated by USGS staff from samples collected once daily (or occasionally more often) during the storms.

APPENDIX F

WATER QUALITY DATA, 1979-1980

TABLE F-1

Water Quality Data - Tucannon River at Tucannon Hatchery

Date	Time (hrs)	G.H.1/ (ft)	Discharge2/ (cfs)	R/F/S3/	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (μmhos/cm)
791110	1430	0.16	39.9	S	6	6.0			
791117	1255	0.19	64.5	S	8	6.5			
791125	1030	0.06	25		7	3.0			
791206	1130	0.27	76.1		7	6.0			72
791210	1145	0.36	112.4		6	4.5			
791213	1420	0.20	60		5	5.0	0.115	5.2	
791214	1400	0.19	58		9.5	5.5			
791219	1410	0.18	55		10	6.5			
791221	1130	0.17	52			5.5			
791223	1130	0.16	50		3.5	2.5			
800104	1225	0.15	40		1	4.0			
800115	1440	1.05	350	F			0.125	12.8	45
800116	1500	0.86	260	F	9.5	6.0			
800122	1200	0.40	119				0.095	4.2	
800210	1145	0.24	71		1.8	3.2	*	1.65	44
800310	1320	0.42	118		9	7.0			45
800316	1500	0.49	138		5.5	5.5			
800328	1100	0.40	119			7.9			52
800331	1120	0.35	103				0.055	2.5	
800410	1230	0.42	125			8.9			
800411	1430	0.42	125			11.0			55
800420	1730	0.78	229			10.8	0.025	5.2	40
800422	1130	0.78	229			7.6			35
800424	1300	0.76	222	S		9.1			37
800427	1500	0.72	215			10.0	0.155	3.4	42
800428	0900	0.80	242			11.0	0.075	2.4	41
800430	1030	0.79	236	R		5.8			
800502	1000	0.77	225			7.0	0.075	4.2	35
800506	1500	0.90	285	R		8.0	0.075	5.4	32
800508	1300	0.77	223.0			10.0			
800509	1400	0.82	252	F		8.5			
800510	1330	0.79	241.2	S	9	7.5			
800512	1500	0.69	230.8	S		11.8			
800516	1700	0.73	219.9	F		9	0.075	3.2	
800928	1700	0.07	44.3	S		14	0.065	1.4	79

1/Observed gage height at the time of collection.

2/Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/Rising, falling, or steady stage.

* NO_3+NO_2 concentration in intragravel waters = 0.100 mg/l.

TABLE F-2

Water Quality Data - Tucannon River above Pataha Creek, at Krouse Ranch

Date	Time (hrs)	G.H.1/ (ft)	Discharge2/ (cfs)	R/F/S3/	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (μmhos/cm)
791111	1530	0.10	73.6	S		7.0			
791125	1420	0.15	75		9	3.9			
791206	1345	0.49	125		8.5	7.0			
791211	1430	0.44	106		3.0	3.0	0.275	3.5	
791213	1030	0.42	78.8		7.5	4.5			
791217	1000	0.39	92		3.0	4.2			
791220	1445	0.38	88.7		8.0	7.0	0.180	3.6	
791222	1600	0.37	85			4.0			
791223	1235	0.36	82			2.5			
791228	1115	0.31	74		1.8	3.5			
800101	0725	0.36	82		3.2	4.5			89
800104	1135	0.34	80		3.5	3.8			
800112	1100	0.60	134	R		4.5		5.0	59
800112	1620	0.84	205	R		4.5		285.	72
800113	1105	1.04	237	R				110.	67
800114	1310	1.55	545	F				86.5	68
800115	1245	1.55	545	F				85	60
800116	1335	1.38	470	F	7.5	5.8			
800118	1450	1.04	310	F		4.5	0.285	15.8	93
800122	1300	0.60	140	S			1.025	6.5	
800203	1350	0.45	107	F	12.5	4.8	0.485	120.	100
800209	1445	0.34	86			6.0	0.915*	8.3	68
800211	1305	0.36	89	S			0.765	6.4	92
800327	1430					9.5			68
800331	1200	0.50	118			9.5			66
800420	1615	1.00	315			13.8	0.075	9.4	55

1/Observed gage height at the time of collection.

2/Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/Rising, falling, or steady stage.

* Concentration of NO_3+NO_2 in intragravel waters drawn from standpipe.

TABLE F-2, continuation

Water Quality Data - Tucannon River above Pataha Creek, at Krouse Ranch

Date	Time (hrs)	G.H.[1] (ft)	Discharge[2] (cfs)	R/F/S[3]	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (μmhos/cm)
800423	1230	1.00	315.8		21.0	12.0			
800427	1245	1.00	315	R		17.0	0.325	6.6	62
800428	1415	1.09	365	S		15.8	0.125	8.4	60
800429	1315	1.30	440	S		13.0			52
800430	1300	1.26	420	F		11.0			50
800502	1120	1.16	340	R		10.2	0.175	10.5	55
800504	1130	1.17	345	S		13.2			
800506	1000	1.31	415	R		10.2	0.275	8.8	50
800508	1100	1.25	330	F		12.0			
800509	1020	1.35	355	R		11.0			
800514	1515	1.08	255	S		15.0			60
800515	1400	1.25	330	R		10.9	0.065	8.4	60
800928	1500	-0.14	42	S			0.025	1.1	100

1/ Observed gage height at the time of collection.

2/ Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/ Rising, falling, or steady stage.

TABLE F-3

Water Quality Data - Pataha Creek at Pomeroy

Date	Time (hrs)	G.H.1/ (ft)	Discharge2/ (cfs)	R/F/S 3/	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (µmhos/cm)
791212	1040	-0.10	9.0	-	5.0	4.5	0.695	162	-
791213	0905	-0.08	9.8	-	5.5	5.5	-	-	-
791215	1050	-0.05	11.0	-	5.0	6.5	-	-	-
791220	1140	-0.05	11.0	-	11.0	7.0	0.925	11.0	-
800105	1135	0.10	19.5	F	0.5	3.5	-	-	-
800112	1830	0.78	62	R	-	-	-	1117.5	142
800112	1920	0.78	62	R	-	-	-	2037.5	100
800113	0145	0.74	64	F	-	-	-	730.0	81
800113	0835	0.50	51	F	-	-	-	259.5	91
800114	1130	0.90	78	F	-	-	-	802.5	75
800114	1830	1.95	162	R	-	-	-	3400.	-
800123	1200	0.05	16	S	- 1.5	3.5	1.475	14.5	-
800202	1545	0.45	49	R	-	-	0.925	935	-
800202	1940	0.75	64	R	-	-	1.755	2250.	118
800203	1000	0.30	39	R?	-	-	1.155	492	-
800203	1640	0.60	62	R	-	-	1.475	1300.	142
800331	1400	0.70	83	-	-	-	1.265	12.0	-
800411	1400	0.17	25	-	20.6	14.5	-	-	160
800420	1200	0.38	48	-	21.1	13.5	0.575	67.0	95
800427	0800	0.35	44	S	-	13.0	0.355	38.0	95
800428	0900	0.37	46	S	-	13.0	0.475	30.0	90
800429	0800	0.45	54	-	-	9.8	-	-	85
800430	0830	0.40	49	-	-	7.0	-	-	-
800502	0810	0.30	38	-	-	11.5	0.455	21.0	100
800504	0830	0.27	35	-	-	12.5	-	-	-
800506	0800	0.26	34	-	-	11.7	0.475	15.4	108
800508	0800	0.23	30	-	-	11.8	-	-	-
800509	0900	0.25	32	F	-	11.0	-	-	-
800514	1000	0.15	22.5	-	-	12.0	-	-	132
800515	1800	0.24	31	F	-	12.2	0.395	16.0	-
800926	1400	-0.15	-	S	-	-	0.865	2.1	230

1/ Observed gage height at the time of collection.

2/ Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/ Rising, falling, or steady stage.

TABLE F-4

Water Quality Data - Pataha Creek at Chard Road

Date	Time (hrs)	G.H.[1/] (ft)	Discharge[2/] (cfs)	R/F/S [3/]	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductanc (μmhos/cm)
791120	1030	0.23	7.2		2.5	1.0			
791125	1410	0.27	8.0		7.0	2.5			
791204	1540	0.79	35.5		-	3.0			
791210	1620	0.31	9.0		0	3.0			
791211	1650	0.32	9.2		3.0	0.5	1.555	18.5	
791212	1000	0.28	8.4		7.0	1.8			
791213	1520	0.32	9.2		8.5	3.8			
791214	1120	0.34	9.8		9.0	4.5			
791215	1005	0.34	9.8		2.0	4.8			
791217	1020	0.34	9.8		3.8	2.0			
791220	0900	0.32	9.2		5.8	5.2	1.325	14.5	
791223	1515	0.36	10.5		3.5	0.8			
791228	1200	0.32	9.2		2.5	1.8			
800103	0900	0.47	14.2		4.0	2.5			
800113	0940	1.19	102		5.6	1.7			
800113	1015	1.19	102					2400.	88
800114	1210	1.74	240	F				2171.	63
800115	1130	1.10	82	F				665.	94
800118	1453	0.76	30.5	F			1.185	72.5	201
800119	1220	0.60	20.5		-1.0	0.2			
800121	1125	0.70	27.4		0.0				
800122	1500	0.62	21.8				1.585	29.0	-
800203	1330	1.10	83					1640	120

1/ Observed gage height at the time of collection.

2/ Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/ Rising, falling, or steady stage.

TABLE F-5

Water Quality Data - Tucannon River at Smith Hollow

Date	Time (hrs)	G.H.[1/] (ft)	Discharge[2/] (cfs)	R/F/S [3/]	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (µmhos/cm)
791112	1100	0.69	84			7			
791120	0945	0.71	91		0	4			
791125	1250	0.75	100		8	5			
791210	1600	0.98	130		7.5	5			
791213	1150	0.85	123		8.0	6.0			
791215	1110	0.84	122		0.5	6.5	0.375	5.7	-
791217	1430	0.82	112		6.0	5.5	-	-	-
791222	1620	0.82	112		2.5	5.0	0.390	4.3	-
791223	1330	0.80	110		3.2	4.0	-	-	-
791228	1135	0.79	107		2.0	4.8	-	-	-
800101	0935	0.80	110		4.0	5.5	-	-	-
800103	1445	0.86	125		3.8	5.5			
800112	1535	1.56	320	R	9.0	4.5	-	1940.	98
800112	1545	1.59	350	R	-	-	-	2075.	99
800113	1220	1.76	422	F?	6.0	5.2	-	870	81
800114	1505	2.24	650	F	-	-	-	1080	64
800118	1145	1.58	345	S	-	-	0.650	49.0	117
800122	1310	1.15	200		-	-	1.175	9.4	-
800203	1415	1.24	230	F,S	12.5	4.5	0.855	850.	115
800310	1115	1.13	170		-	7.0	-	-	90
800316	1215	1.29	242		9.0	6.5	-	-	-
800331	1325	1.09	180			-	0.275	6.2	-
800420	1530	1.58	345			15.0	0.075	15.0	73
800423	1445	1.63	363			13.0	-	-	-
800425	1245	1.53	338			13.5	-	-	-
800427	1135	1.51	320			16.0	0.275	8.4	75
800428	1400	1.55	335			17.0	0.175	8.8	78
800429	1120	1.72	404	R		12.0	-	-	70
800430	1445	1.69	390	F		17.0	-	-	65
800502	1145	1.62	358	R		11.5	0.175	24.0	70
800506	1100	1.64	372	R		11.5	0.365	10.1	65
800508	1000	1.56	320	S		11.9	-	-	-
800509	1100	1.65	374	R		12.8	-	-	-
800514	1220	1.42	284	S		15.0	-	-	72
800515	1445	1.56	320	R		13.0	0.275	88.0	-

1/ Observed gage height at the time of collection.

2/ Discharge from stage-discharge relation. If flow is given to the nearest 0.1 cfs, discharge was measured immediately before or after collecting the sample.

3/ Rising, falling, or steady stage.

TABLE F-6

Water Quality Data - Tucannon River at Powers Road

Date	Time (hrs)	G.H.[1/] (ft)	Discharge[2/] (cfs)	R/F/S [3/]	Air T (^oC)	Water T (^oC)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (µmhos/cm)
791119	0900	0.10	125		8.5	5.5			
791120	0900	0.09	115		1.0	4.0			
791125	1330	0.09	115		8.5	5.9			
791130	1300	0.00	72		4.0	2.9			
791210	1530	0.11	130		6.0	4.5			
791211	1615	0.10	125		5.0	3.8	0.475	5.95	
791213	1325	0.10	125		8.0	6.0	0.425	7.3	
791214	1155	0.10	125		11.0	7.0			
791217	1415	0.10	125		5.0	6.0			
791222	1645	0.10	125		1.5	5.0	0.420	4.5	
791223	1420	0.10	125		2.5	4.0			
800112	1400	0.54	360	R				3572	128
800112	1520	0.59	385	R				4860	132
800113	1300	0.86	525	S	6.0	5.2		810	91
800114	1645	1.20	705	F				1245	83
800122	1325	0.35	255	F			1.175	17	
800202	1545	0.45	305	R					141
800203	1440	0.46	315	F				3915	136
800208	1730	0.18	165				0.315	80	
800310	1150	0.37	265			10.0			100
800328	1700	-	-	F		11.0			101
800331	1340	0.34	245				0.425	5.9	
800410	1500	0.28	220	R		12.5			
800420	1430	0.50	335	R		16.0	0.025	70.0	80
800423	1530	0.49	330			15.0			
800428	1530	0.49	330	R		18.0	0.275	6.0	85
800429	1230	0.59	385	R		18.0			75
800430	1530	0.61	395	F		14.5			70
800502	1210	0.51	340	R		12.5	0.355	29.0	75
800504	1100	0.50	335	S		14.5			
800506	1205	0.59	385			12.5	0.275	12.0	172
800508	1030	0.50	335	F		12.0			
800509	1200	0.58	375	S		13.9			
800514	1345	0.39	280			15.0			75
800515	1530	0.49	330	S		13	0.125	44	
800925	1415						0.105	2.1	153

1/ **Gage Height, on staff plate, in feet.**

2/ **Discharge, as estimated from discharge rating curve.**

3/ **Rising, falling, or steady flow.**

Table F-7. Water Quality Measurements, 1979-1980

Miscellaneous Stations, Tucannon River Basin

Station 1/	Date	Time (hrs)	G.H. 2/ (ft)	Discharge 3/ (cfs)	R/F/S 4/	Air T (°C)	Water T (°C)	NO_3+NO_2 as N (mg/l)	Turbidity (NTU)	Specific Conductance (µmhos/cm)
Helley Fletcher Ranch	800209	1210	-	138				1.075	27.5	
								0.985*		
Camp Wooten	800210	0900	-	81	S	-2.5	2.4	0.075	2.5	40
								0.115*		
								0.900*		
Marengo site	800210	1450		87			4.2			58
	800211	1220		87	S			0.450	6.4	79
	800328	1300		147			10.5			62
	800331			125				0.025	2.6	
	800427			236				0.075	4.8	
	800429	1200		285						
	800502			271				0.075	5.4	
	800928	1700		55				0.075	1.4	91
King's Grade bridge	800211	1240		90	S			0.555	3.5	84
Site 9.5 miles d/s of Marengo	800211	1245		92	S			0.575	6.5	89
U.S. 12 bridge	800211	1300		102	S			0.780	6.2	90
Linville Gulch near mouth	800210	1700	-	-				2.875	39	305

1/ On Tucannon River, unless otherwise specified.

2/ No staff gages at these locations.

3/ Discharge estimate for Camp Wooten is observed discharge at P79G-A (plus 10 cfs to account for diversions to the Hatchery); estimated discharge at Marengo is the average of the daily means at P79G-A and G-B; at Fletcher's Ranch, the average of the daily means for P79G-E and G-F are used to provide an estimate of discharge.

4/ Rising, falling, or steady stage.

* NO_3+ NO_2 concentrations in samples of intragravel waters drawn from standpipes.

APPENDIX G

NET AND MAXIMUM SCOUR OR FILL

(Net Material Added To or Removed From Bed)

Table G-1. Material Removed or Added to the Bed at Hatchery Habitat Site

Tucannon River, WY 1980

Cross Section	Date	Mean Bed Elevation[a] (ft)	Change In Mean Bed Elevation[b] (ft)	Maximum Point		Width[c] (ft)	Distance Along Channel (ft)	Material Removed (-) or Added (+)		
				Scour (ft)	Fill (ft)			Volume[d] (ft^3)	Tonnage[e] (tons)	Tonnage/Unit Length Channel (tons/mile)
A-1	800322 800928	95.96 96.02	-0.94	0.60	0.80	45	23	-972		
A-2	800322 800928	95.17 95.01	-0.16	1.01	0.18	43	38	-261		
A-3	800322 800928	95.43 95.38	-0.05	0.31	0.39	69	35	-120		
A-4	800322 800928	95.09 95.24	+0.15	0.22	1.27	66	44	+435		
A-5	800322 800928	94.10 94.12	+0.02	0.26	0.34	62	53	+65		
A-6	800322 800928	93.57 93.50	-0.02	0.25	0.30	54	36	-136		
Total for Site							229	-989	-59	-1368

[a] Mean bed elevation is difference of the water surface elevation and mean depth (computed as quotient of cross-sectional area and top width).
[b] Difference in mean bed elevations during first and second surveys.
[c] Width of bed from bank to bank including all bars below 1980 high water mark.
[d] Width x distance along channel x change in mean bed elevation.
[e] Assumed unit weight of 120 lbs. per cubic foot.

Table G-2. Material Removed or Added to the Bed at Krouse Ranch Habitat Site

Tucannon River, WY 1980

Cross Section	Date	Mean Bed Elevation[a] (ft)	Change In Mean Bed Elevation[b] (ft)	Maximum Point		Width[c] (ft)	Distance Along Channel (ft)	Material Removed (-) or Added (+)		
				Scour (ft)	Fill (ft)			Volume[d] (ft^3)	Tonnage[e] (tons)	Tonnage/Unit Length Channel (tons/mile)
B-1	800111	100.69								
	800925	101.06	+0.32	0.30	0.50	44	25	+352		
B-2	791111	100.22								
	800924	100.55	+0.33	0.64	0.83	44	25	+363		
B-3	800111	100.37								
	800925	100.37	0.00	0.80	0.55	44	39	0		
B-4	800111	100.15								
	800925	100.31	+0.16	0.70	0.90	54	54	+466		
B-5	800111	99.81								
	800924	99.87	+0.06	0.70	0.78	55	64	+211		
A	800323	99.22								
	800925	99.33	+0.11	1.45	0.91	55	68	+411		
B	800323	99.21								
	800925	99.07	-0.14	0.71	1.09	55	54	-415		
C	800323	99.21								
	800925	99.32	+0.11	0.83	1.05	53	65	+0.11		
Total for Site							404	+1766	+106	+1385

[a] Mean bed elevation is difference of the water surface elevation and mean depth (computed as quotient of cross-sectional area and top width).
[b] Difference in mean bed elevations during first and second surveys.
[c] Width of bed from bank to bank including all bars below 1980 high water mark.
[d] Width x distance along channel x change in mean bed elevation.
[e] Assumed unit weight of 120 lbs. per cubic foot.

Table G-3. Material Removed or Added to the Bed at Marengo Habitat Site

Tucannon River, WY 1980

Cross Section	Date	Mean Bed Elevation[a] (ft)	Change In Mean Bed Elevation[b] (ft)	Maximum Point		Width[c] (ft)	Distance Along Channel (ft)	Material Removed (-) or Added (+)		
				Scour (ft)	Fill (ft)			Volume[d] (ft^3)	Tonnage[e] (tons)	Tonnage/Unit Length Channel (tons/mile)
G-1	800319	97.67								
	800927	97.57	-0.10	0.88	0.21	78	28	-218		
G-2	800319	97.27								
	800927	97.22	-0.05	0.60	0.25	68	34	-115		
G-3	800319	97.12								
	800927	97.03	-0.09	1.15	0.28	73	44	-289		
G-4	800319	96.68								
	800927	96.58	-0.10	0.80	0.10	68	51	-346		
G-5	800319	96.00								
	800927	95.98	-0.02	0.40	0.30	70	42	-58		
G-6	800319	95.90								
	800927	95.94	+0.04	0.40	0.26	77	32	+98		
Total for Site							231	-928	-56	-1273

[a] Mean bed elevation is difference of the water surface elevation and mean depth (computed as quotient of cross-sectional area and top width).
[b] Difference in mean bed elevations during first and second surveys.
[c] Width of bed from bank to bank including all bars below 1980 high water mark.
[d] Width x distance along channel x change in mean bed elevation.
[e] Assumed unit weight of 120 lbs. per cubic foot.

Table G-4. Material Removed or Added to the Bed at Camp Wooten Habitat Site

Tucannon River, WY 1980

Cross Section	Date	Mean Bed Elevation[a] (ft)	Change In Mean Bed Elevation[b] (ft)	Maximum Point		Width[c] (ft)	Distance Along Channel (ft)	Material Removed (-) or Added (+)		
				Scour (ft)	Fill (ft)			Volume[d] (ft^3)	Tonnage[e] (tons)	Tonnage/Unit Length Channel (tons/mile)
H-1	800318 800929	96.90 96.88	-0.02	0.24	0.48	36.0	22.0	-15.84		
H-2	800318 800929	96.81 97.29	+0.10	0.22	0.38	36.5	23.0	+83.95		
H-3	800318 800929	96.66 96.55	-0.11	0.22	0.38	34.0	34.0	-127.16		
H-4	800318 800929	96.97 97.02	-0.05	0.20	0.20	50.0	31.0	-77.50		
H-5	800318 800929	96.57 96.44	-0.09	0.22	0.16	47.0	47.0	-198.81		
H-6	800318 800929	95.83 95.85	+0.02	0.29	0.26	68.0	62.0	+84.32		
H-7	800318 800929	94.53 94.43	-0.10	0.36	0.24	35.0	33.0	-115.20		
H-8	800318 800929	94.89 94.85	+0.01	0.24	0.24	29.5	26.0	+7.67		
H-9	800318 800929	93.96 93.98	+0.02	0.30	0.43	42.3	30.0	+25.38		
H-10	800318 800929	93.59 93.59	0.00	0.43	0.37	41.8	28	+35.11		
Total for Site							336	-298	-18	-281

[a] Mean bed elevation is difference of the water surface elevation and mean depth (computed as quotient of cross-sectional area and top width).
[b] Difference in mean bed elevations during first and second surveys.
[c] Width of bed from bank to bank including all bars below 1980 high water mark.
[d] Width x distance along channel x change in mean bed elevation.
[e] Assumed unit weight of 120 lbs. per cubic foot.

Table G-5. Material Removed or Added to the Bed at Fletcher's Ranch Habitat Site

Tucannon River, WY 1980

Cross Section	Date	Mean Bed Elevation[a] (ft)	Change In Mean Bed Elevation[b] (ft)	Maximum Point Scour (ft)	Maximum Point Fill (ft)	Width[c] (ft)	Distance Along Channel (ft)	Material Removed (-) or Added (+) Volume[d] (ft^3)	Tonnage[e] (tons)	Tonnage/Unit Length Channel (tons/mile)
J-1	800323	95.23								
	800926	95.13	-0.10	0.38	0.23	66	31	-204		
J-2	800323	94.94								
	800926	94.75	-0.19	0.96	0.44	56	34	-361		
J-3	800323	94.66								
	800926	94.42	-0.24	1.47	0.18	64	43	-660		
J-4	800323	94.73								
	800926	94.49	-0.24	0.82	0.25	85	41	-836		
J-5	800323	94.64								
	800926	94.56	-0.08	0.95	0.20	70	32	-179		
Total for Site							181	-2240	-1344	-39206

[a] Mean bed elevation is difference of the water surface elevation and mean depth (computed as quotient of cross-sectional area and top width).
[b] Difference in mean bed elevations during first and second surveys.
[c] Width of bed from bank to bank including all bars below 1980 high water mark.
[d] Width x distance along channel x change in mean bed elevation.
[e] Assumed unit weight of 120 lbs. per cubic foot.

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